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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H04J 1/00, 1/02, H04M 11/00

A1

(11) International Publication Number: WO 98/02985

(43) International Publication Date: 22 January 1998 (22.01.98)

(21) International Application Number: PCT/US97/12045

(22) International Filing Date: 11 July 1997 (11.07.97)

(30) Priority Data:
60/021,651 12 July 1996 (12.07.96) US

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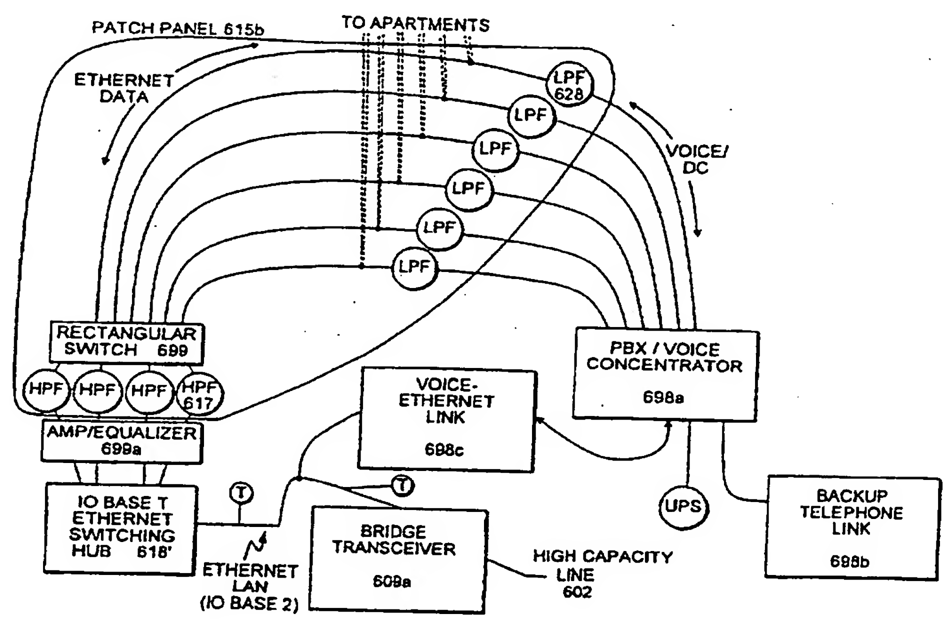
(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, US, UZ, VN, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: DIGITAL COMMUNICATION SYSTEM FOR APARTMENT BUILDINGS AND SIMILAR STRUCTURES USING EXISTING TELEPHONE WIRES



(57) Abstract

A digital communication system for apartment buildings and similar structures using existing telephone wires includes a switching hub (618') for directing information from a source selectively to ones of a plurality of switch lines as signals in a selected frequency band that exceeds frequencies of voice signals on a telephone link, a switch (699) for coupling each switch line selectively to one of m phone lines, and circuitry for controlling the switch (699).

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DIGITAL COMMUNICATION SYSTEM FOR APARTMENT BUILDINGS AND SIMILAR STRUCTURES USING EXISTING TELEPHONE WIRES

Cross Reference to Related Applications

This application references U.S. patent applications Serial No. 08/431,270 filed April 28, 1995 entitled "VIDEO TRANSMISSION SYSTEM UTILIZING INTERNAL RESIDENCE TELEPHONE LINES", Serial No. 08/670,216, filed June 21, 1996, entitled "RF BROADCAST SYSTEM UTILIZING INTERNAL TELEPHONE LINES", Serial No. 08/816,059, filed March 11, 1997, entitled "CABLE TELEVISION DISTRIBUTION AND COMMUNICATION SYSTEM UTILIZING INTERNAL TELEPHONE LINES", and Serial No. 08/814,837, filed March 11, 1997, entitled "TWO-WAY RF COMMUNICATION AT POINTS OF CONVERGENCE OF WIRE PAIRS FROM SEPARATE INTERNAL TELEPHONE NETWORKS".

U.S. Serial No. 08/431,270, filed April 28, 1995, entitled "VIDEO TRANSMISSION SYSTEM UTILIZING INTERNAL RESIDENCE TELEPHONE LINES" is a continuation of Serial No. 08/181,562, filed January 13, 1994, now abandoned, which is a continuation of Serial No. 08/062,148 filed May 14, 1993, now abandoned, which is a continuation of Serial No. 07/688,864, filed April 19, 1991, now abandoned, which is a continuation of Serial No. 07/379,751, filed July 14, 1989, now Patent No. 5,010,399.

U.S. Serial No. 08/670,216, filed June 21, 1996, entitled "RF BROADCAST SYSTEM UTILIZING INTERNAL TELEPHONE LINES", is a continuation of Serial No. 08/545,983, filed October 20, 1995, now abandoned, which is a continuation of Serial No. 08/376,921, filed January 23, 1995, now abandoned, which is a continuation of 08/255,355, filed on June 8, 1994, now abandoned, which is a continuation of application Serial No. 08/114,976, filed August 31, 1993, now abandoned, which is a continuation of application Serial No. 07/803,135, filed

December 5, 1991, now abandoned, which is a continuation-in-part of application Serial No. 07/688,864, filed April 19, 1991 (hereinafter "U.S. patent application Serial No. 08/431,270"), now abandoned, which is a continuation of application Serial No. 07/379,751, filed July 14, 1989, now Patent No. 5,010,399.

U.S. Serial No. 08/816,059, filed March 11, 1997, entitled "CABLE TELEVISION DISTRIBUTION AND COMMUNICATION SYSTEM UTILIZING INTERNAL TELEPHONE LINES", is a continuation of application Serial No. 08/674,117, filed July 1, 1996, now abandoned, which is a continuation of application Serial No. 08/545,983, filed October 20, 1995, now abandoned, which is a continuation of Serial No. 08/376,921, filed January 23, 1995, now abandoned, which is a continuation of Serial No. 08/255,355, filed on June 8, 1994, now abandoned, which is a continuation of application Serial No. 08/114,976, filed August 31, 1993, now abandoned, which is a continuation of application Serial No. 07/803,135, filed December 5, 1991, now abandoned, which is a continuation-in-part of application Serial No. 07/688,864, filed April 19, 1991 (hereinafter "U.S. patent application Serial No. 08/670,216"), now abandoned, which is a continuation of application Serial No. 07/379,751, filed July 14, 1989, now Patent No. 5,010,399.

U.S. Serial No. 08/814,837, filed March 11, 1997, entitled "TWO-WAY RF COMMUNICATION AT POINTS OF CONVERGENCE OF WIRE PAIRS FROM SEPARATE INTERNAL TELEPHONE NETWORKS", which is a continuation of application Serial No. 08/673,577, filed July 1, 1996, now abandoned, which is a continuation of application Serial No. 08/545,937, filed October 20, 1995, which is a continuation of Serial No. 08/372,561, filed January 13, 1995, now abandoned, which is a continuation of Serial No. 08/245,759 filed on May 18, 1994, now abandoned,

which is a continuation of 08/115,930, filed August 31, 1993, now abandoned, which is a continuation of 07/802,738, filed December 5, 1991 (hereinafter "U.S. patent application Serial No. 08/816,059"), now abandoned, which is a continuation of 07/688,864, filed April 19, 1991, now abandoned, which is a continuation of Serial No. 07/379,751, filed July 14, 1989, now U.S. Patent No. 5,010,399 (hereinafter, the "parent application").

Background of the Invention

The invention relates generally to digital communication over existing lines in residential structures. The development and popularity of the computer communication network called the Internet has spurred much excitement. Although there are many services provided by the Internet that people enjoy, there is a common complaint that data does not flow downstream (that is, towards the end user) at a rate that is sufficient to support many of the applications that are in demand.

An effort to use municipal coaxial cabling networks to provide connections for cable TV subscribers to the Internet has begun. New devices called "cable modems" have enabled adaptation of these coaxial networks to Internet computer communication.

The coaxial cabling in place in most localities is installed in a "tree-and-branch" manner. This allows for a very high downstream data rate, which is one reason why the cabling can be used for these Internet connections. It is very difficult, however, to use this cabling for an upstream (that is, away from the end user) data path at other than very low data rates. The best alternative seems to be the use of ordinary telephone lines to provide an upstream path. This either adds to the cost

or ties up a line. Another difficulty is that cable modems are extremely sophisticated devices and their use will make the cable system expensive. Finally, the coaxial wall outlets in a residence are not, in general, located where connection of computers is convenient.

The municipal coaxial cabling networks represent, unfortunately, the only existing conductive pathways that can economically support a very high downstream communication data rate from a central location to individual residences in the surrounding areas. As a result, there is no satisfactory solution to the problem of inadequate downstream and upstream Internet bandwidth.

Summary of the Invention

The present invention relates to two-way communication of signals, particularly digital signals, over telephone wires between the various residential units in an apartment building or similar structure and a point where the wires in the building converge, for example, on the ground floor, while the wires continue to fulfill their original function as a conductive path for voice signals. A dedicated digital path is created, in this manner, between each apartment unit and a communications hub located at the point of convergence or hub. A high capacity line connects between this hub and a part of a larger network, such as the well-known Internet. This completes the connection between the residents upstairs and an external communications network.

A particular advantage of the invention is that the residents can share access to the high-speed line in such a way that each resident can enjoy nearly its full capacity. This is possible because typical residents make short "bandwidth demands," or requests for "dedicated" access to the line at very infrequent

intervals as, for example, a demand for one second of access each minute. The result is that the line is dormant and therefore fully available to the other residents during the other 59 seconds. Ultimately, of course, a resident will have to wait for access, at least for a short period, when many other people in the same building are also engaged in communication activities.

The invention also provides for the use of these telephone wires to enable the tenants to concurrently access video signals that are brought to the same point of convergence. Finally, the invention includes methods for reducing the effect that reflections in the internal wiring can have on transmitting signals at frequencies above voiceband. Some of these methods may be particularly useful in using the telephone wiring internal to single family homes for communication of data and video.

This invention is partly an outgrowth of technology presented in the parent application (Patent No. 5,010,399) and the three continuations-in-part thereof (U.S. Patent applications Serial Nos. 08/431,270, 08/670,216, 08/816,059, and 08/814,837). They are all incorporated herein by reference.

Most of the technology disclosed in the Patent No. 5,010,399 and U.S. patent application Serial No. 08/431,270 relates to the transmission of telephone signals and non-telephonic signals (such as cable television signals, other video signals, audio signals, data signals, and control signals) across telephone wiring networks of a general nature. Many of the elements disclosed in U.S. patent application Serial No. 08/670,216 are particularly appropriate for transmission within typical single family residences, while the main focus of U.S. patent application Serial No. 08/816,059 is

communication through apartment buildings and similar structures.

This invention takes advantage of the opportunities made available by the unused frequencies that exist on the telephone wiring in apartment buildings. In part, the invention is directed towards the use of a wiring network internal to apartment buildings to inexpensively establish a digital connection between the tenants and an outside communication line. By establishing such connections according to the invention, and by connecting multiple buildings together in a specially cooperative network, the problem of slow data flow, described above, can be significantly reduced at relatively low cost. This is one objective of the invention. An additional objective is to provide the digital communication capability while allowing for simultaneous communication of video over the same conductive pathways. A third objective is to economically overcome some of the untoward effects that splits in internal wiring have on the use of these wires for non-telephonic communications.

Methods described in the previous applications are extended herein. The focus of these extensions is to provide for better communication over these wires using less expensive hardware, and to provide a solution that is less costly to install and operate. For example, the use of the Manchester coding system and other elements of classical Ethernet LANs (local area networks), is extended to telephone networks, resulting in a digital communications network which operates in a manner that is virtually identical to classical Ethernet LANs. Methods are also disclosed for using the particular data networks described herein for the transmission of digital video signals.

Because the invention can also be used in single family homes in addition to apartment buildings, provision is made for adapting the invention for use in those types of structures as well.

Brief Description of the Drawing

FIG. 1a is an overview of a system for allowing tenants in an MDU (multiple-dwelling unit) to access multiple video and data sources brought to the point where the telephone wires converge.

FIG. 1b is a splitter for connecting both voiceband and broadband signals.

FIG. 1c shows the principles of the transceiver.

FIG. 1d shows the processor, a principle component of the transceiver.

FIG. 2 shows the major system components in the wiring closet.

FIG. 3 shows the principle components of the communications hub.

FIG. 4a is a diagram of a patch panel for combining and separating multiple signals of different varieties.

FIG. 4b is a diagram of a patch panel for combining and separating voiceband and broadband signals.

FIG. 5 shows the principle components of a modem for transmitting data in an apartment unit over active telephone lines.

FIG. 6 is a diagram of a modem that does not load the communication line.

FIG. 7 shows the details of the modem in FIG. 6.

FIG. 8a is a diagram showing how to use two pairs of active internal wiring to connect a 10BaseT adapter.

FIG. 8b is a diagram showing how to use a 10Base2 adapter over a single pair.

FIG. 9a is a diagram showing how to connect to a 10BaseT hub over the internal wiring of a multiple dwelling unit.

FIG. 9b is a diagram showing how to connect 10Base2 Adapters to a 10BaseT hub

FIG. 9c is a diagram showing how to connect 10BaseT Adapters to a 10BaseT hub using a single pair.

FIG. 10a shows a low data rate LAN that uses the internal wires of an MDU.

FIG. 10b shows a second low data rate LAN that uses the internal wires of an MDU.

FIG. 11 shows a data communications network established across a group of MDU buildings.

FIG. 12 shows a modulator that can transmit either video or data.

Description of the Preferred Embodiments

An Overview of the System

FIG. 1a shows the type of twisted pair network typically found in apartment buildings and other "multiple dwelling units," hereinafter referred to as MDUs. The configuration is typical because multiple wire pairs fan out from a point of convergence, reaching each of the residential units in the building, which are called local networks 411.

In most apartment buildings, each unit is served by two or more of these wire pairs. The wiring splits inside each unit, terminating at wall jacks at different locations. Often, both telephones and broadband devices connect to these jacks, the telephones communicating with local exchange 475 and the broadband devices communicating with a high-speed line 402 through transceiver a 400. (Voice signals are expressed at baseband using frequencies below 3 KHz. Signals whose energy is confined to frequencies above 3 KHz, by contrast, are referred to herein as broadband signals.)

In FIG. 1a, telephone devices 414a, b, and c are shown connected to one of the jacks. Each telephone connects through a low pass filter. These jacks can follow the design of splitter 161, shown in FIG. 1b. Splitter 161 includes filters which block RF energy from transmitting between the telephone devices and the wiring, and also provides a termination at RF frequencies to prevent reflection of RF energy back onto the network.

FIG. 1a also shows a digital device, computer 495c, connected to the wiring through a digital transceiver 491c. This transceiver exchanges digital signals with a transceiver/switch 400. The basic principles of transceiver 495c are shown in FIG. 1c. That figure shows digital transmitter 178 and digital receiver 179, and how they communicate digital signals over a network of active telephone wiring. As described in U.S. patent application Serial No. 08/816,059, transceiver 491c combines the functions of these two devices together so that they transmit and receive signals through the same connection to the wiring.

FIG. 1a shows components of the systems called Local Network Interfaces 404a, b, and c. These represent electronic processors connected to the wiring at a point just before the wires reach their destination, (that is the individual apartment units), and split off towards the various terminations. Local Network Interfaces 404 are provided to assist in the communication process. An example would be the placing of an amplifier in the wiring closet on each floor of the building. However, these interfaces are not strictly required. Configurations can implemented where the Local Network Interface is absent, and signals run over the wiring directly from the convergence point to the terminations (in the tenant's apartment) without active or passive processing at any intermediate location.

FIG. 1d shows processor 418, which is the principle component of transceiver 400. This is the "nerve center" of the apartment communication system described in U.S. patent application Serial No. 08/816,059. It applies signals onto the wires leading to the residential units up above, receives broadband signals applied to the wiring by the transmitters that connect at the terminations in the local networks 411, provides the switching necessary to direct signals to their proper locations, and exchanges signals with a high-speed communication line 402.

The following topics are covered in the next four sections:

1. Connections at the point of convergence of the wire pairs
2. The digital communications hub
3. Patch panels -- separation of voice and broadband signals
4. Signal flow and processing in the apartment units
5. Two-way communication using one pair of wires and two frequency bands

These sections describe the processing used to allow individuals in a large structure to efficiently share a high speed connection to a digital communication network. Subsequent sections will describe much more specific systems that provide extra functionality and economy.

1. <u>Connections at the Point of Convergence of the Wire Pairs.</u> FIG. 2 illustrates the telephone connections to an apartment building. Telephone service is typically provided to tenants in apartment buildings in the following manner. A bundle of wire pairs from the central telephone office arrive at a patch panel 612 in the master wiring closet in the basement of the building. Panel 612 allows cross connection of these wires with the

internal wires that lead from the closet upwards to apartment units 611. An internal line is made active when it is cross-connected to one of the outside lines terminating in panel 612. In the US, typical apartment units are served by at least two internal pairs.

Some apartment buildings include a private telephone switch to which all tenants connect. Such a switch, also called a PBX, is functionally identical to the central office of the telephone company. Referring to FIG. 2, it is clear that the validity of the teachings of this invention are not affected when the "central office" is replaced by a PBX.

To install a broadband system in a building, broadband panel 615 is installed in the wiring closet, and a "detour" through this panel is created for each twisted pair 616 that will carry broadband signals to or from an apartment unit. These pairs 616 exchange signals with hub 618 through patch panel 615. In other words, signals are added to pairs 616, transmitting in the direction of the apartment units, and signals transmitted in the opposite direction are stripped from the pairs and transmitted to hub 618. The details of separators 613 and panel 615 are described later.

2. The Digital Communications Hub

The functions performed by digital communication hub 618 are a subset of the functions performed by processor 418, in FIG. 1d. Both processor 418 and hub 618 are designed to manage two-way communication with multiple destinations in a single structure that are served by twisted pairs that converge at a common point. As described in U.S. patent application Serial No. 08/816,059, processor 418 manages communication of signals of all varieties, and also manages communication between one destination and another, and between each

destination and the outside communication line. Hub 618, by contrast, manages only digital communications, between the one destination and another, and, especially, between one destination and an outside communication line.

The details of hub 618 is shown in FIG. 3. Hub 618 receives signals from communication line 602, converts these signals to a time-multiplexed digital Bitstream, separates the signal into individual bitstreams, and applies the individual bitstreams to the twisted pairs leading to the appropriate destinations. When processing signals flowing in the reverse direction (that is, to the line 602), hub 618 inputs digital signals from the various telephone lines leading from patch panel 615, time-multiplexes them together into a high-speed Bitstream, and applies this Bitstream to communication line 602.

Hub 618 includes interface 609. Interface 609 performs the function of exchanging signals with a high speed communication line 602. There are many different methods for performing that exchange, one of which is frequency modulation/demodulation to separate the frequencies of signals applied to line 602 from those received from it. Manchester encoding could also be used separate these frequencies.

Signal collection subsystem 607 represents the part of hub 618 that receives digital signals at broadband frequencies from twisted pairs 678 that lead from broadband patch panel 615. (These pairs ultimately lead to the individual apartment units.) Demodulators 608 represent the parts of subsystem 607 that convert the received signals from broadband frequencies to baseband, thereby creating a datastream of digital signals. Processor 614 then uses time-domain multiplexing to combine them into a single datastream that is passed to interface 609. Signal distribution subsystem 603

represents the part of hub 618 that separates a digital Bitstream into many digital signals at lower data rates, and applies them onto the twisted pairs leading to the broadband patch panel 615. Processor 606 is the part of subsystem 603 that separates a time-multiplexed datastream into its individual signals. Modulators 610 represent the part of subsystem 603 that converts each of the lower-rate digital signals to broadband frequencies before passing them to broadband patch panel 615.

Modulators 610 and demodulators 608 may not work by modulating a carrier wave in the classical style. A method called Manchester coding can be used to express digital sequences as electrical signals that will transmit across the wiring at frequencies above the voiceband. Manchester codes are the same as the codes used in standard LAN (local area network) technologies such as Ethernet and Token Ring systems. Manchester codes are bi-level square waves that transition at the midpoint of every time interval used to encode a bit. This transition provides timing information, and extra transitions encode the data. Manchester coded signals do not have energy at DC and have little energy at low frequencies. As a result, no additional modulation of the waveform is necessary to place the signal completely above the voiceband, and the signal output by standard LAN products can be passed directly through a hi-pass filter onto the wiring. (Such a high pass filter is necessary to block voiceband energy.) These types of signals can also be interpreted directly by the receiver without classical demodulation. As a result, if subsystems 607 and 603 are designed to send and receive signals encoded using the Manchester method, modulators 610 actually work by converting (that is modulating) classical square waves into bi-level square waves with a

fixed transition pattern. Demodulators 608 work by performing the reverse process.

Other versions of subsystems 603 and 607, which include additional functionality, are illustrated in hub 618', 618a, and 618b, which are shown in Figs 9a, 10a, and 10b of this application and described below.

3. Patch Panel 615 - Separation of voice and broadband signals

FIG. 4a shows the details of one version of patch panel 615 labeled 615a. A simpler version of the patch panel shown in FIG. 4b will be described later. The signals outputted through the ports of hub 618 are passed through broadband patch panel 615a, before they are transmitted to the apartment units 611. Broadband signals sent from the apartments also pass through this panel as they flow towards hub 618. These signal pathways are now described in greater detail.

To connect a tenant's computer to hub 618, at least one of the pairs leading to the tenant's apartment unit is detoured through panel 615a. Panel 615a is composed of a collection of signal separators 613a, 613b and 613c. As shown in Figs 2 and 4, broadband signals reach one of signal separators 613 by transmitting along pairs 616 from the tenants apartment unit or by transmitting along pairs 678 leading from hub 618. Voice signals flow through the separators from the central office to the tenants' apartment units and back.

Separators 613 use passive processing to guide broadband signals from pairs 616 (in FIG. 2) onto the correct ones of pairs 678 (in FIG. 2), and to guide signals transmitting in the opposite direction in a similar manner. In doing so, they receive signals that

transmit at different frequency bands on a single pair, and separate them by applying them onto different ones of multiple pairs. They also combine signals, at different frequencies, from multiple pairs onto a single wire pair. Different types of separators are described below.

Separator 613a is an example of a junction that allows digital signals to flow in opposite directions on the same wire pair. Digital signals headed downstream (towards the tenant) pass through a coupling junction 623 that is internal to 613a. Junction 623 prevents downstream signals from reversing directions by taking the alternate path down through the junction. High pass filter 622 is located downstream of the junction, and it blocks the voiceband signals from flowing towards Hub 618. The digital signals pass though filter 622 and continue on to the tenant's apartment. The voiceband signals, meanwhile, reach the upstairs apartment after passing through low pass filter 621 that blocks the digital signals from flowing towards the central office.

In the opposite direction, digital signals applied to the telephone wires in the tenant's apartment pass through high pass filter 622 and through coupling junction 623 towards demodulators 608 in Hub 618. Ordinarily, the two digital signals must cover different frequency bands in order to prevent interference while flowing upstream and downstream on the same wire pair. (Important exceptions to this restriction are described later on.)

In separator 613b, the upstream and downstream signals servicing a tenant flow over different wires pairs. Signals transmitting upstream towards hub 618 transmit over the left pair. They encounter a simple split in the wiring but are blocked from exiting towards the central office by low pass filter 627 shown on one

branch of the split. Instead, they continue through high pass filter 624 and flow towards hub 618. High pass filter 624 prevents voice band signals from transmitting towards the hub.

Broadband signals flowing in the opposite direction (downstream) use the second twisted pair that services the same apartment. These signals lead from hub 618 through high pass filter 625, while telephone signals pass, in both directions, through low pass filter 626 that prevents RF energy from flowing towards the central office.

The second twisted pair passing through separator 613c also illustrates a different concept. It routes through separator 613c which allows video signals at frequencies higher than the data to flow onto the wire pair and transmit towards the tenant. Internal to separator 613c, the video and data signals converge at coupler 630, which prevents either signal from flowing back towards the opposite signal source. They continue on through band pass filter 628, which blocks energy outside of the bands occupied by the two signals

At the same time, control signals used to control the video source are created in the tenant's apartment. These signals are converted to electrical form and transmitted onto the wiring, reaching separator 613c. (Numerous ways of applying control signals to the wiring are shown in the previous applications.) They flow through the patch panel but are blocked by band pass filter 628, passing instead through band pass filter 629 on the way to electronics that can receive and interpret their information. Band pass filter 629, meanwhile, blocks the video and digital signals from transmitting towards these electronics.

To more clearly illustrate the signal flow through separators 613b and 613c, an example of the combination

of video, data, and control on the same wire is now given. Assume the digital signal flowing through these separators is an Ethernet signal with energy between 3 MHZ and 18 MHz. Assume further that a video source frequency modulates a 27.5 MHz carrier, expressing the video information between 20 MHz and 35 MHz. Because the digital and video signals are separated in frequency by 2 MHZ, they can readily transmit on the same wire without interference. Meanwhile, the control signal could occupy, for example, the frequencies between 1.5 and 2 MHz, and also avoid interfering with those two. Bandpass filter 629, in this case, would pass frequencies between 1.5 and 2 MHz, while bandpass filter 628 would pass frequencies between 3 and 35 MHz. High pass filter 625, in separator 613b, would pass all the frequencies between 1.5 and 35 MHz, because the video, data, and control signals are not separated in that component. Low pass filter 626 would pass only the voiceband, blocking the three broadband signals from transmission towards the central office.

FIG. 4b shows patch panel 615b, which is a simpler version of patch panel 615. The simplicity is due to the fact that there is no separation or combination of two different broadband signals on the panel. Rather, the separation and combination of broadband signals in accomplished internal to hub 618 and internal to the electronic transceiver that locates in the tenant's apartment unit and is described below. The passive electronics on panel 615b only separate broadband signals from voiceband signals, and only combine a broadband signal onto a pair that conducts a voiceband signal and nothing else. Low pass filter 628 and high pass filter 617 are used to perform these functions, which are described many times in the preceding applications.

4. Signal Flow and Processing in the Apartment Units

FIG. 5 shows the communication processes in the tenant's apartment unit Modem 645a exchanges signals between PC 646 and hub 618 through patch panel 615.

Modem 645a connects to the wiring through splitter 634. Within splitter 634, low pass filter 631b allows the voiceband signals to reach the telephone, while blocking broadband signals, thereby preventing a telephone device from loading down broadband energy. The digital signals transmitting between the hub 618 and the modem 645a pass through high a pass filter 631a. High pass filter 631a blocks the voiceband signals from transmitting towards modem 645a. Splitter 634 is similar to splitter 161 in FIG. 1b but does not have the terminator 163.

The signals arriving at the modem 645 through the splitter 634 pass through a coupler 643 and pass through band pass filter 640 to a digital demodulator 636. That component converts the analog waveform of the signal into a digital Bitstream. The resulting Bitstream reaches digital diplexer 637 which sends the data to the computer. Digital signals transmitted from the computer 646, are received by the diplexer 637 and are passed to digital modulator 635. That device converts the digital Bitstream to an analog waveform, which flows through band pass filter 641, through coupler 643 and high pass filter 631a, and onto the internal wiring. The bandpass filters 641 and 640 prevent the analog signals passing through coupler 643 from crossing over towards the opposite sections of the modem.

The analog signals passing onto the internal wiring split and transmit in two directions. If the energy of the signal is high enough, however, sufficient strength will appear at the one of demodulators 608, that is the companion to modem 645 and is located in the wiring closet.

Digital modulator 635 works in coordination with one of demodulators 608 (FIG. 3), and digital demodulator 636 works in coordination with one of modulators 610 (FIG. 3) in hub 618. The modulators use coding to express digital information as analog waveforms, and the coding procedure must be correctly interpreted by the demodulators in order for the Bitstream to be correctly reproduced.

Digital diplexer 637 is simply a digital device that includes the means to establish two-way communication with a port on a PC or other type of computer. In the preferred embodiment, this diplexer will be designed to communicate with the parallel ports that are common to most PCs. The parallel port is a good choice because it can be inexpensively added to the computer, it can accommodate two-way digital communication at high data rates, and digital diplexer 637 can be designed to emulate one of the many devices that communicates through such a port in this manner. Such emulation would allow the PC to use approximately the same software that is designed to communicate with the device being emulated.

5. Two-way Communication Using One Pair and two Bands

The most common interaction on the Internet is the downloading of data from a server to an end user. This is what makes the demand on the "downstream" bandwidth much higher than the demand on the "upstream" bandwidth. There are a few applications, such as video conferencing, where a high upstream capacity is required. Even in these systems, however, the downstream data rate requirements are likely to be much higher.

The lower upstream requirement means that the upstream data can be expressed within a narrower frequency band. In the invention, the narrow band makes

it easier to find enough spectrum on a single twisted pair for the expression of both signals. Expressing both the upstream and downstream signals on a single pair has many advantages. First of all, it leaves all the frequencies (that is the spectrum) on the second pair open for other types of communication, such as the transmission of analog video described in Patent No. 5,010,399 and in subsequent continuations in part. A second advantage is that the path established by the second wire pair is often broken at intermediate wiring closets and at some of the telephone jacks in the apartment unit. As a result, confining all communication to the first path can decrease the amount of preparation necessary to begin service to a particular unit. Perhaps the most important advantage to using a single wire pair is that communication can be conducted across wiring where a four-conductor bundle serves an apartment unit and all conductors are twisted together rather than twisted in pairs. This type of wiring is sometimes called "quad," and is often used to reach from the "local wiring closet" found on the floor of each apartment building to the individual units on that floor. Because of the nature of the twisting, there will be very high crosstalk between one wire pair and any second pair. Effectively, this may mean that a "quad" cable includes only one wire pair that is available for RF communication.

An example of the expression of both the upstream and downstream signals flowing between a single apartment unit and hub 618 is now given. Assume that modulator 610 (FIG. 3) in subsystem 603 receives a Bitstream at 2 Mbs from processor 606. Modulator 610 can then use the common encoding scheme called frequency shift keying (FSK) to express this Bitstream as an analog waveform confined within, for example, 5-10 MHz. This signal

transmits through patch panel 615b (FIG. 2) and reaches digital demodulator 636 in modem 645 (FIG. 5). That component recreates the 2 Mbs digital Bitstream and passes it through digital diplexer 637 to computer 646, thereby completing the downstream path. In the opposite direction, the PC creates a Bitstream of only 1 Mbs. This signal can also be converted to an analog waveform using FSK, and is slow enough to be expressed in only 3 MHz of bandwidth, as between the frequencies of 1-4 MHz. It can, as a result, flow between digital modulator 635 and digital demodulator 608 in subsystem 607 without interfering with the downstream signal, because the two do not overlap in frequency.

Improving the Data (and Video) Link over the Network Wiring

Much of the foregoing discussion described processing that is likely to be common to many systems that meet the specific challenge of allowing individuals in a large structure to efficiently share a high speed connection to a digital communication network. Later, more detailed systems for meeting this challenge are described. Before that description, however, the invention includes new methods that are useful in the communication of high-speed data and other broadband signals over telephone wires in general, and over active internal telephone networks in particular.

1 Removing All Reflections and Loadings from the Internal Wiring.

The Patent No. 5,010,399 and U.S. patent application Serial No. 08/431,270 described the use of low pass filters to remove the loading affects of telephone devices that may connect to the wiring network. As described, if all telephone devices connect through a

low pass filter, they can all continue to operate normally and will have no affect on high-frequency energy. These filters are shown, among other places, as part of in splitter 161, in FIG. 1b. All telephone devices connected to a network of wiring can be inexpensively filtered in this manner.

Other loadings can be caused by connection of broadband devices that receive energy from the wiring. In this section, a method of connecting these devices that does not disturb the existing signal flow is described.

Reflections are caused by open terminations and splits in the wiring. U.S. patent application Serial No. 08/431,270 described the use of a terminator in splitter 161 to suppress reflections at the end of an open termination. As described in that application, however, splitter 161 can cause a substantial reduction of energy flowing through the network if it is connected at the end of a very short stub. An example is where the various jacks in a network are all connected by a process known as "daisy chaining."

Referring to FIG. 6, if one ignores, for the moment, the wire leading from jack 642a to jack 642b, the remaining conductive paths illustrate an example of "daisy chaining." Note that a single wire pair leads successively from one wall jack to the next, (that is from 642a, to 648, to 649,) providing a connection opportunity at each jack. Many apartment units are connected in such a manner. If splitter 161 were connected at jack 642a, its termination would unnecessarily drain energy from the wiring.

It is always possible to identify a straight path leading from one "open" termination to another, and to consider this to be the main path, or "bus," and to consider all other wiring as part of a branch. In FIG.

6, for example, it is natural to identify jack 649 as one termination and hub 618 as a second termination, with jacks 648 and 642a connected in between. The path leading from jack 642a to jack 642b would be an example of a branch. Note further that extra branches are created if broadband transmitters and receivers connect at intermediate jacks 642a and 648, either at the end of a long cord or in such a way as to load the energy on the wiring. Were a video receiver to connect at jack 642a, for example, significant energy would flow towards the receiver.

When energy encounters a branch in twisted pair wiring, reflections can occur as a result of some energy being reflected back towards the source. Another type of reflection can occur if an "open connection" terminates the branch. Energy reflected from an open termination may return to the main path, but with a time delay relative to similar signals on that path. Even when reflected energy does not cause substantial interference, energy flowing down the main path is reduced by a branch. If all such branches and affects are eliminated, and terminations are added at the ends of the main path, the transmission becomes well behaved -- signals applied to the main path, or bus, simply split and half of the energy transmits towards each termination, where it gracefully exits the bus.

Methods to suppress reflections caused by connection of high frequency devices and by naturally occurring branches are now described. Referring to FIG. 6, splitter 661 is designed to allow connection of a broadband device without causing reflection problems. It connects to jack 648 with a zero impedance, so no splitting or reflection of energy can occur. Signals can be received from the main path because processor 632 detects the voltage variations of the signal as it flows

past the wall jack, without disturbing or loading down the signal flow. The detected signal is then amplified and sent on to the broadband device, which is modem 645 in the case of Fig. 6. The cord that issues from splitter 661 can be very long, yet it will not affect the signal flow on the main path of the internal wiring.

Signals transmitted onto the wiring through splitter 661 simply flow through the zero impedance connection, only adding to the signals on the main path. These signals split, transmitting towards the terminations at either end.

Note that splitter 661 also includes terminator 669 that connects behind high pass filter 664, at the same point that processor 632 connects. Switch 671 allows one to break the connection (at high frequencies) between this terminator and the wiring. The terminator should not be connected when the wiring runs past a jack in "daisy-chain" style, as it runs past jack 648 in FIG. 6. Such a connection would drain energy from the line before it can flow on to jack 649 downstream.

By contrast, it is important that the terminator be connected when splitter 661 connects to a jack at the end of a segment of wiring, such as jack 649 in the lower right part of FIG. 6. This connection terminates the line at broadband frequencies, allowing the energy to "exit gracefully" without causing a reflection. Processor 632 can still detect the broadband signal energy, if one is present, because the signal flows past its point of connection. (Note that a similar terminator is required where the internal wiring connects to hub 618, down in the wiring closet. This defines that opposite end of the transmission "bus", and will be discussed below.) Note that splitter 161, which is connected at jack 649, provides the termination used in FIG. 6.

Now consider the issue presented when the branch leading to jack 642b actually connects to the internal wiring at jack 642a. This may be referred to as a "natural" branch, because it is not a result of connecting a high frequency device to the main path.

This branch may be a wire leading to some other part of the apartment not shown in the diagram. Because there is nothing to prevent signal energy flowing from hub 618 from splitting, at that branch, energy will be diverted away from broadband devices that may connect at jacks 648 and 649. Also, reflections may be created at jack 642b, causing some energy to reflect back towards jack 624a.

The reflections and diversion of energy can be suppressed by opening the wall jack and placing low pass filter 647 on the part of the branch nearest jack 642a. This will make the RF signal flow behave as if there were no branch connected at that jack. Fortunately, most such branches are created at wall jacks, so easy access is usually available to the point where the filter should connect. Furthermore, low pass filters are made in the form of well-known "split magnetic cores," which can be connected to the wiring in a "snap on" manner, that is without even making a break in the wire to connect the filter.

A possible drawback to the use of low pass filter 647 in this manner is that it prevents the operation of a broadband device at the end of the branch. A good solution is available, however, when the internal wiring consists of more than one pair, as is typical. LPF 647 will not affect the second pair, and broadband signals can use that pair to flow towards jack 642b at the end of the branch. A similar low pass filter (not shown), however, must be installed along the second pair that leads from jack 642a to jack 648. Placement of both

these filters would create, effectively, two special paths. One path would allow broadband energy to flow, on the first wire pair, directly between hub 618 and jack 649, without any splits whatsoever, and without any devices that could drain energy from the line. The second path would allow flow of energy between jack 642b and hub 618 in exactly the same manner.

When a second pair exists but the wiring is of the "quad" type, where the four conductors are all twisted together, the creation of two paths in this manner may not be possible because of the likelihood of large amounts of crosstalk. One can either tolerate the splits created by the junction at jack 642a, or use low pass filter 647 to simply block broadband energy from jack 642b. Yet another alternative (not shown) is to place a sophisticated coupler at the 3-way junction. In theory, such a junction could prevent reflections on all branches, and allow signals to split cleanly when crossing a junction in any direction.

The details of splitter 661 are shown in FIG. 7. Low pass filter 663 connects directly to the internal wiring, blocking the broadband energy from transmitting to any telephone that may connect. Terminator 669 and processor 632 connect behind high pass filter 664, which blocks signals in the voiceband.

Switch 671 interposes between terminator 669 and the wiring. Switch 671 is provided to defeat (that is disconnect) the termination when needed. As described above, the terminator should not connect when the internal wiring runs past the jack and on to a second location. A possible improvement is to provide an adjustment mechanism (not shown) that can vary the resistance that creates the termination. This will allow the impedance to be more closely matched to the line, making the suppression of reflections more certain.

Splitter 661 is designed to be used with Modem 645, which is a slight variation on modem 645, shown earlier. One difference is that bandpass filters 641 and 640, and coupler 643 are not included. Another difference is that two wire pairs connect between modem 645 and splitter 661, and signals flow in only one direction on each pair.

Key to processor 632 is amplifier 665. This device detects the voltage variations created by the signal on the internal wire as it flows past the wall jack towards the termination. These variations can be sensed through high pass filter 664, coupler 668, and band pass filter 660. Amplifier 665 sends the amplified signals towards demodulator 636 at a specified energy level. Amplifier 665 is powered by a DC source in modem 645, as shown in FIG. 7. The DC power is separated from the other signals on the wire by the series of high and low pass filters shown in the diagram. Alternatively, amplifier 665 can be connected directly to a DC power source.

In the opposite direction, signals from modulator 635 flow through amplifier 662a and band pass filter 662 to coupler 668. That junction applies 30 dB attenuation to signals crossing towards band pass filerter (BPF) 660, so it prevents amp 665 from picking up the signal from modulator 635. The small amount of energy crossing towards amp 665 is blocked by filter 660. Signals continue onto the wiring and immediately split, transmitting towards the terminator at jack 649 (FIG. 6) and the terminator (described later on) at hub 618 down in the wiring closet.

2 <u>Using Telephone Wiring as a 10Base2 Bus -- Single Pair, SameBand used for Up and Downstream Flow</u>

When reflections in the main transmission path have been minimized, as provided in the previous section,

modulator 635 can transmit signals within one frequency band, and demodulator 636 can receive the signals sent from hub 618 within the same band. The well-known 10Base2 computer communication network sends signals between stations over a single conductive path in exactly the same manner.

Such a system can work because signals sent from hub 618 will be terminated by splitter 161 at wall jack 649 -- they will not reflect back towards to the wiring closet. As described above, signals sent from modulator 635 will also reach that termination, as well as the termination at hub 618.

The only possibility of confusion can occur at coupler 668. As described above, signals sent from modulator 635 cannot reach demodulator 636 because coupler 668 attenuates signals flowing along the path from 635 to 636. (Band pass filters 662 and 660, which were provided for extra separation, will not be effective when signals communicate at the same frequencies.) A similar mechanism allows hub 618 to send and receive signals within the same band.

There may be several ways to implement coupler 668. An example of such a device is the "hybrid" junction found in common telephones. (Common telephones, of course, communicate signals in opposite directions over a single pair within the same frequency bands.) Ideally, coupler 668 will include an adjustment mechanism, so that the separation can be "tuned" to account for minor variations in the characteristics of the wiring and the electronics at the specific site.

To coordinate with modem 645, demodulator 608 and modulator 610 must also transmit and receive signals within the same frequency band. The same methods that are used in splitter 661 can be used to create this property in those devices.

Transmitting Analog Video when Reflections and Loadings are Suppressed.

As described in the preceding applications, transmission of ordinary analog video in ordinary 6 MHz AM NTSC format is possible over short distances of telephone wiring such as are found in single family homes. When transmitting NTSC video below the tunable range, a mechanism must be provided to shift the signals in frequency so that they again fall within the range of a TV tuner. This involves extra expense, an expense that could be saved if the signals were transmitted within tunable channels.

But transmission over tunable channels is more difficult because signal energy attenuates more quickly, with distance, when the energy is expressed at higher frequencies. Other factors, however, also contribute to attenuation, and if these factors can be alleviated, the attenuation due to transmission distance alone may not be enough to adversely affect the picture. (The required minimum thresholds for SNR and signal energy are described in Patent No. 5,010,399 and in U.S. patent application Serial No. 08/431,270.) In U.S. patent application Serial No. 08/431,270, for example, the possibility of using tunable channels is suggested as potentially feasible if the attenuation due to all connected telephone devices is suppressed by low pass filters. (This type of attenuation is known as "loading.")

The methods described above, which suppress all splits within the network, reduce the signal attenuation of the digital signals described herein, but they can also can be used to reduce the attenuation of any other broadband signal in exactly the same manner. The attenuation is reduced in the following ways:

As described above, when a signal encounters a split, a small amount of energy reflects back to the source, while half of the remaining energy, in general, transmits down one branch and half transmits down the other. Assuming the target receiver is located downstream of one of the branches, suppression of the reflection and diversion saves slightly more than half of the energy lost.

The attenuation due to transmission along the cord connecting from a jack to the device is eliminated by the affect of the amplifier in active splitter 661.

Additionally, one of the methods disclosed in U.S. patent application Serial No. 08/670,216 can be used, in harmony with the methods described herein, to counter attenuation in single family homes. This is the method where video signals transmit from the source to a repeater unit at the telephone interface, are reamplified and transmitted along a second branch towards the video destination. Effectively, this shortens the transmission distance by as much as a factor of two.

Because these savings are substantial, these methods can significantly increase the number of internal networks over which transmission of analog video can succeed within a tunable channel.

Establishing a Common Ethernet LAN over the Internal Wires of MDUs and other Structures

Two different types of Local Area Networks are described in this section. Each of these networks uses the telephone wires internal to an MDU to communicate between the computers of the network and the point of concentration located in the telephone wiring closet.

System A (the preferred embodiment) - A 10BaseT Connection In Each Apartment

If there are at least two twisted pairs leading from an apartment unit down to the wiring closet in the basement, these pairs can, in theory, be used to connect a 10BaseT Ethernet adapter directly to an Ethernet hub. The challenge is made easier, of course, if all reflections are removed from the two paths.

Such an arrangement is shown in FIG. 8a, which shows the electronics in the apartment unit. Low pass filters 647, 647a, and 647b confine the high frequencies along the dedicated path between hub 618′ and powered splitter 691 which connects at jack 648. There are no reflections along this path because there are no splits. (In FIG. 8b, Filters 647, 647a, and 647b provide filtering on each of the two pairs.)

Note that the cord connecting powered splitter 691 to jack 648 need not be short. That is because the technology, described in the last section, is not used for the solution which is shown in FIG. 8a and 9a. In particular, the broadband devices do not connect to the wiring in the style of a bus.

Ordinarily, a 10BaseT Ethernet adapter only requires an ordinary two-pair connection to a hub, so long as the length does not exceed 100m and the wiring meets certain specifications. In this case, however, several problems may arise. These problems and their corresponding solutions (shown in FIG. 8a) are described below.

Voice signals are on the line. High pass filters 692a are provided to block to the voiceband.

- A telephone device can load down the energy. Low pass filter 692b is provided to block high frequencies from those devices.

There may not be a good match between the impedance of the line and that of the adapter. Impedance matcher (IM) 694a corrects for these types of mismatches

on the wire pair over which signals arrive at the adapter. Impedance matching and balancing (IMB) circuitry 694b corrects for similar mismatches on the opposite pair, and also balances the signal across the two leads of the line before applying it to the wiring. IM units 694a and 694b should be manually adjustable, so that the impedance matching can be conveniently and correctly established upon installation.

The wiring may attenuate the signal more than the Ethernet spec allows, and higher frequencies may attenuate more, vis-à-vis the lower frequencies, than is allowed under spec. (This relative attenuation difference is also called "tilt.") Amplifier/equalizer 695a corrects for tilt on the first wire pair, and 695b provides gain and corrects for impending tilt by "pre-emphasizing" the signal that is about to be applied to the second pair.

It may be noted that broadband devices cannot connect to either of jacks 649, 642a, or 642b, because broadband energy does not reach those jacks. This is necessary to reduce splits, and while this is somewhat limiting to the tenant, powered splitter 691 can be removed and connected at either of the other jacks to operate in the same way. All that is required is to shift the position of low pass filters 647, 647a and/or 647b. (For example, connecting powered splitter 691 at jack 649 would require LPF 647b to be disabled, and for all telephones that connected to jack 648 to be filtered. Connecting powered splitter 691 at jack 642a would require LPF 647b to connect near jack 642a, along the path towards jack 648.) Special wall jacks that include such low-pass filters and allow a user to easily enable or disable them would allow a user to quickly perform this shift. Methods for designing these jacks will be

clear to those skilled in the art of building connectors and switches for twisted pair systems

[Line Powered Devices. Nearly all telephone devices have excess DC power made available to them by the telephone system that establishes the communication. The public switched telephone system (PSTN) is no exception. This allows devices connected to the wiring network to derive power through that connection, as many ordinary telephones derive power for illumination of their dial pads. While there are severe legal restrictions on the power that can be derived from the PSTN, such restrictions do not apply to systems driven by PBX electronics, or similar devices. Deriving power for powered splitter 691 will eliminate the need for a separate power supply and will reduce the amount of wiring required to complete all connections.

In FIG. 8a, DC power supply 691a is shown connected behind low pass filter 692b. (Power will be available at that point, but not behind filters 692.) Those skilled in the art will be able to design 691 so that it can derive power for the operation of amplifiers 695. This concept can be extended further, allowing the network to supply power for the 10BaseT adapters, or other devices that connect to powered splitter 691 at port 691b. Yet another good solution is to use an empty pair to make power available throughout the network. If such a pair is available, this may be the best alternative.]

The electronics in the wiring closet are shown in FIG. 9a. The major components in this diagram are Ethernet Switching Hub 618', bridge transceiver 609a, rectangle switch 699, and patch panel 615b.

(The diagram also includes PBX/voice concentrator 698a, voice-ethernet link 698c, and backup telephone link 698b. These devices are used to join the voice traffic

to the data traffic on a common external line. Except for that important function, they do not play a role in the systems described herein.)

Bridge transceiver 609a can be any device that: connect to a group of devices connected together according to a local area network standard, such as the 10Base2 Ethernet standard, and can connect to a communications line that ties into the Internet to exchange signals with that line, and either performs the addressing functions necessary to direct signals to the correct destinations on the local area network, or coordinates with devices that perform such addressing.

In the preferred embodiment, bridge transceiver 609a is one half of an Ethernet Bridge transceiver pair. Together with the companion pair, it constitutes what is known as an Ethernet Bridge.

When connected to a group of computers (or other digital devices) that are connected together according to the Ethernet local area network (LAN) standard, a bridge gives the local network the property of being an "ethernet segment." The segment is composed of the computers or other digital devices that connect to this LAN.

The bridge connects to a second LAN, which also becomes an ethernet segment. The dataflow between the two can be increased by adding an extra bridge transceiver pair as an additional link between each of the two segments. One property of the bridge is that data applied by one station that is destined for a second station on the same LAN does not flow across the bridge. (The LAN connected to bridge transceiver 609b is shown in FIG. 11 and the manner in which these two ethernet segments coordinate is described later on.)

An example of a remote bridge is the BestLan2 bridge which is carried in the catalog of the well-known

Black Box Corporation. The BestLan2 bridge consists of two companion transceivers. As described, one transceiver connects to one Ethernet segment, and the second connects to a different segment. They allow 2 million bits per second to flow from one segment to another. If a second BestLan bridge is established, of course, the data rate connecting the two segments becomes 4 Mbs.

Switching hub 618' is a common Ethernet 10BaseT switching hub. It has a multiple number of 10BaseT ports through which Ethernet adapters can connect via two twisted pair wires. Typically, it also has one port for establishing a connection to a 10Base2 bus. In the preferred embodiment, it connects to bridge transceiver 609a via this port. (Voice-Ethernet Link 698c may also connect to this 10Base2 bus.) Hub 618' exchanges signals with line 602 through that connection. All other connections to hub 618' are through standard 10BaseT twisted pair ports.

The 10BaseT adapters in the apartment units connect, ultimately, to the 10BaseT ports on hub 618'. These connections are made through patch panel 615b, shown in the upper left. The filters on patch panel 615b are the same as those on patch panel 615a, and they provide the same filtering. (Panel 615b includes rectangular switch 699, which is not part of panel 615a and is described below.)

Signals transmit between the 10BaseT adapters and hub 618' by transmitting through high pass filters 617 and powered splitter 691. The effect of 617 and 691 is to adapt the wiring so that this communication functions, for all practical purposes, exactly like 10BaseT hubs that are used in a more recognizable system.

The switching property of hub 618' protects the privacy of the individual tenants. Without this property, all signals flowing through hub 618' are transmitted to all of the connected 10BaseT adapters. While the 10BaseT adapters are normally set to intercept only data tagged with their address, overriding that protection is not difficult.-- leaving open the opportunity for monitoring a neighbor's communication. When switching is provided, signals flow only to their intended destinations.

Rectangular switch 699 is provided to economize on the number of ports that must be included on hub 618'. In theory, the number of required ports is equal to the maximum number of users that may connect at any one time. Because this is likely to be far less than the total number of users that subscribe, that is that have the ability to connect, one need not include one port for each subscriber. As a result, the number of ports on hub 618' can correspond to the maximum number of users that one may expect at any one time. This will correspond to the number of ports on the input to switch 699. The dimensionality of the output, on the other hand, should be equal to the total number of subscribers. Clearly, some mechanism of controlling switch 699 is required, and it is clear that one can be developed by those skilled in the art of switching and control. For example, a cross point switching circuit could be used as the rectangular switch.

Amplifier/equalizer section 699a is provided to do the following at each port of hub 618':

boost the power of the signals transmitted out through the port

apply pre-emphasis to the transmitted signals to compensate for impending tilt

tightly balance the transmitted signals across the twisted pairs

match the impedance of the port to the transmission line

equalize the signals input by the port, thereby compensating for spectral tilt, and

increase the energy level of the input signals.

These functions extend the distance over which hub 618' and the 10BaseT adapters can reliably communicate. Note that it is most efficient to perform these processes before the dimensionality is expanded by rectangular switch 699.

Focusing now on the voice processing, PBX/voice concentrator 698a intercepts all voice traffic in the building, and converts it to a coded Bitstream. This data is applied, via voice/Internet link 698c, to the 10Base2 LAN that connects hub 618' to bridge transceiver 609a. The data is addressed for "PSTN" link 673, shown in FIG. 11 and described later on.

In the event of the failure of this link, telephone communications would be suspended. Telephone backup 698b is provided to ensure emergency connections. Backup 698b can be any telephone link that is activated "on-demand" and makes the telephones in the building active.

System B - Using a 10Base2 Adapter over an Empty Pair. Consider FIG. 8b, where modem 645a represents an ordinary Ethernet 10Base2 card. This figure will illustrate a method of using this common adapter to establish an Ethernet LAN by connecting computers to the network hub over internal wiring. In particular, this method is attractive when there is at least one "inactive" twisted pair leading from the apartment unit down to the wiring closet.

Establishing such a capability is important because there may be situations where external factors, such as warranty contracts on PBX systems, prevent the connection of external devices to active wiring. (When no PBX is present, warranties are not an issue but governmental regulations are. Fortunately, the low pass filters 628 can be made to block any energy that might be in violation. These regulations, and the filters necessary to meet them, are described in U.S. patent application Serial No. 08/816,059 and the Patent No. 5,010,399.)

[The 10Base2 adapter connects to adapter 661a, which is an optional device. Adapter 661a is only needed when the communication is to be conducted over an active twisted pair. The pair in question is assumed to be inactive, at the outset of this discussion, and description of adapter 661a is deferred.]

Low pass filters 647 and 647a block broadband frequencies at two of the paths leading away from jack 642a. As a result, signals transmit directly between modem 645 and hub 618 and do not split at jack 642a or anyplace else. (Note that the cord connecting to modem 645 cannot cause a split because it is part of the main transmission path. The technology, described above, that prevents connecting cords from creating splits is not required in the examples of 8b and 9b.) Thus, the wiring between the two devices acts as a standard 10Base2 bus, so long as a termination is provided at modem 645a (as indicated by the circled T in figure 8a, and also at hub 618.)

The processing in the wiring closet is nearly identical to the processing shown in FIG. 9a. The only difference is in the electronics, shown in FIG. 9b, that connect between hub 618' and switch 699. In FIG. 9b, no high pass filters are required because the line is not

active. Instead, Media converters 679a and baluns 679b are interposed between the switch and the hub. The baluns 679b convert the path from a single twisted pair to a single coax, which is the natural media for 10Base2. The converters 679a , which are available as inexpensive, off-the-shelf devices, perform the exact coordination necessary for 10Base2 devices to connect to 10BaseT hubs. In particular, the coax media of 10Base2 is replaced with two twisted pair wires, and coordination of the different collision detection schemes of the two systems is provided. Preferably, they would also include the amplification and equalization functions embodied in amp/equalizer 699a.

It remains to show how to adapt the 10Base2 collision detection system to operate over a twisted pair that conducts voiceband signals. This is not straightforward because the 10Base2 adapters coordinate to avoid detections by signaling each other at DC. Specifically, the 10base2 adapter creates a "DC offset" on the bus to signal its intention to transmit. Other adapters sense this and react accordingly.

To adapt the collision detection system of 10Base2 adapters, adapter 661a includes means (not shown) to provide the following:

Block DC signals with a low pass filter.

Provide impedance matching between the twisted pair wires and the coax port of the 10Base2 adapter.

Detect the DC offset from 645a, create a tonal frequency in response, and apply the tone to the line.

Detect tones applied to the line by a similar adapter connected to hub 618. Create a DC offset at the connection to 645 in response to these tones.

The media converters, 679a, shown in FIG. 9b must be adapted to recognize that collision detection is

signaled by a tone and not a DC offset, and to react accordingly.

System C - 10BaseT & 10Base2 Adapters that use a single twisted pair as a Bus. (The preferred embodiment for single family homes.) Referring to Figs 6 and 7 assume that modem 645b is a standard Ethernet 10BaseT card. (Functionally, this assumption is sound, because modem 645b connects to a PC and exchanges signals through two twisted pairs.) Because all reflections from the wiring are suppressed, the 10 Mbs Manchester code signals, created by 645b, will transmit, in the style of a bus, over the single pair to which splitter 661 connects. These signals transmit towards the terminators at jack 649 and at hub 618.

Note that 10BaseT cards use Manchester codes to communicate both their data signals and their collision detection signals. As a result, both of these signals will transmit across the bus between jack 649 and hub 618.

It remains to show how these signals would coordinate with a 10BaseT switching hub. (A 10BaseT hub is the best choice for hub 618 because it is the only inexpensive piece of hardware that performs the switching functions necessary to protect privacy.) The electronics in the wiring closet are nearly the same as those shown in FIG. 9a. The only differences are shown in FIG. 9c. That figure shows how diplexers 679c replace amp/equalizer 699a. Also, a termination is provided between each diplexer and hi pass filter 617.

Diplexers 679c connect to detect signals without loading the bus. These signals are passed to the twisted pair providing input to a port on the 10BaseT hub. Signals issued by the hub are picked up from the second pair by the diplexers, and applied to the bus, ultimately reaching 10BaseT adapter 645a in the apartment unit. In

the preferred embodiment, diplexers 679c also perform the amplification/equalization ordinarily provided by 699a.

It is noted that, where privacy is not a concern, use of a 10BaseT hub is not required. This has major implications for use in single family homes. In particular, multiple 10BaseT adapters can connect, each through splitter 661, to a "bus" created from the internal wiring in the manner shown in FIG. 6 and described above. These adapters will then communicate with each other over this bus without the aid of a hub -- just as 10Base2 cards communicate over a stretch of coaxial cable. Each adapter will all receive all data signals and collision signals applied by each of the other cards -- exactly as if they had been connected to a 10BaseT hub.

For example, referring to FIG. 6, assume 645b is a 10BaseT adapter, and assume a second 10BaseT adapter is connected (through a second splitter 661) to jack 642a. If a low pass filter is connected between hub 618 and jack 642a, and terminator 669 in the second splitter 661 is connected, the "bus" will reach between jack 642a and the termination at jack 649. The two 10BaseT cards will be able, at that point, to freely communicate across this stretch of wiring. Were other jacks available along the bus, additional 10baseT adapters could connect and communicate in the same manner.

It is further noted that 10Base2 adapters can connect directly to a bus, without the aid of splitter 661, and no reflections will occur if the connecting cord is not too long. (One way to do this is to connect a "pocket-style" 10Base2 adapter to a wall jack using a very short cord, and use a long cord to connect to the parallel port on a PC.) In order that the collision signaling work properly, however, the twisted pair that serves as the bus must be empty -- it cannot be used for

telephone communications. If these conditions are met, the 10Base2 adapters will communicate as they do over standard coaxial cables.

Networks for Wiring that will Not Support 10 Mbs.

As described above, the wiring in some apartment buildings is not of sufficiently reliable quality for support of 10 Mbs communication. The factor of communication reliability, however, trades off directly with communication data rate, so these problems can be addressed by establishing lower data rate communications over the apartment wires.

In the following two sections, two systems for establishing such communications are described. The major advantage of these designs are that they require relatively inexpensive electronics, they allow all tenants in the building to share access to one or more high speed lines, and they guarantee the privacy of all who use the system.

In both systems, it is suggested that a data rate of 2 Mbs between the basement and each tenant be used. While this rate is significantly less than 10 Mbs, the data rate may be limited below 10 Mbs by other factors. Also, the advantage of the extra 8 Mbs may be that the user can download a graphic in .2 seconds instead of 1 second, a difference that may not be appreciated.

System A - Ethernet Adapters are Used for Routing.

The first system is now described in terms of the major components shown earlier. Hub 618a, which differs from hub 618 only in that its description is more detailed, is shown in FIG. 10a. Hub 618a consists of bridge transceiver 609a, bus 619, and modems 650a.

The function of bridge transceiver 609a, in this system, is the same as the function it played in the system described above. Specifically, bridge transceiver

609a can be any device that: can connect to a group of devices connected together according to a similar LAN (local area network) standard, such as the 10Base2 Ethernet standard, and can connect to a communications line that ties into the Internet to exchange signals with that line, and either performs the addressing functions necessary to direct signals to the correct destinations on the LAN, or coordinates with devices that perform such addressing.

In the preferred embodiment, bridge transceiver 609a is one half of an Ethernet Bridge transceiver pair. Together with its companion pair, bridge transceiver 609b, it constitutes what is known as an Ethernet bridge, and the LAN in the wiring closet is called an Ethernet Segment. These concepts were described in greater detail above.

Modems 650a include modulators and demodulators that apply signals on to the twisted pairs and recover signals transmitting from the apartment units up above. They correspond to modulators 610 and demodulators 608, shown in FIG. 3. (It is noted that, together with bus 619, which is described below, modems 650a perform the same processing as subsystems 603 and 607, described above.)

Modems 650a and bridge transceiver 609a connect to bus 619, and can apply data to and recover data from that bus. Data applied to the bus transmits to all other devices connected to the same bus. Communication is therefore established between all devices that connect to bus 619. In the preferred embodiment, the common 10Base2 standard governs communication across this bus.

Bus 619 connects the modems together into an Ethernet LAN. (As described above, this LAN also becomes an Ethernet network "segment" when bridge transceiver 609a connects to its companion transceiver.) Bus 619 can

follow the standard of the common 10BaseT hubs, the 10Base2 bus, or similar mechanisms. In the case of 10Base2, the "hub" is simply a thin coaxial cable, or bus, that is terminated at both ends. The digital stations on the network connect to the bus through a high impedance, picking up the signals without disturbing or otherwise loading down the flow of signal energy. Signals applied to the bus transmit to both ends, where their energy is removed by the terminators.

There is one modem for each tenant that subscribes to the service provided by the system described in this section. Part of each modem 650a is Ethernet NIC 653, which does processing equivalent to a Network Interface Card, or NIC. A NIC is the common piece of electronics that connects between computers and a network hub or bus. Each NIC senses all the signals flowing across the bus, and selects only those that are tagged with the same "address" that is encoded on the NIC. These signals are passed to the data bus of the computer. In summary, a NIC provides the processing necessary to exchange signals between the computer bus (to which it connects) and the network bus (or hub) while protecting the privacy of others on the network.

While providing a two-way communication path, a typical NIC also uses the computer's processing power to manage some of the processing it (the NIC) conducts. Microprocessor 654 is included in modem 650a for this specific purpose. This eliminates the need for NIC 653 to make use of a processor in a large computer. (Such a need would significantly increase the cost of the hub.) A design for hub 618a whereby one microprocessor 654 performs this function for several of modems 650a would be preferred.

The signals recovered by the NIC are passed to "first in first out," (FIFO) queue 655, hereinafter

referred to as FIFO 655. That device is a digital buffer and matches the speed at which data flows across the network with the speed of the data flowing between the modem and the subscriber. FIFO 655 can be implemented by well-known electronic circuits.

The focus now moves to the question of how fast modem 650a should pass data to its associated computer. If a common Ethernet technology is used, 10 million bits per second (Mbs) will flow across the network. But the maximum data rate is more likely to be limited by remote bridge 609a, and bridges become very expensive when they are called on to accommodate a very high data rate. Because of the availability of relatively inexpensive wireless bridges, such as the BestLan2, that communicate at 2 Mbs, a data rate of 2 Mbs link to the tenant may be a good choice.

Data flows across an Ethernet LAN, however, in bursts of 10 Mb/s, even if data arrives at the network at a slower speed. As a result, NIC 653 must pass data downstream at a rate of 10 Mbs. Under those circumstances, NIC 653 will fill the buffers of FIFO queue 655 at the rate of 10 Mbs, but only in relatively short "bursts." The buffers must be emptied, or read out, at the rate of 2 Mbs, and the capacity of the buffer will determine the possibility of an overflow. Clearly, the buffers should be large enough to make such possibility very small.

The FIFO operates under control of MPU 654 and its buffers are read out towards modulator 657. That device expresses the digital energy as a waveform confined to frequencies above the voiceband, and passes it to broadband patch panel 615. Various methods, such as QPSK (quadrature phase shift keying) or the Manchester coding described earlier, can be used to encode the information at frequencies above the voiceband.

The analog waveform created by modulator 657 is passed through band pass filter 658 and coupler 651 and onto the twisted pair leading through broadband panel 615 and towards the tenant's apartment.

Modem 650a also receives signals sent from the tenant's apartment. These signals are applied by modem 645a, as shown in FIG. 6. They transmit through broadband panel 615, through coupler 651 and band pass filter 652 in modem 650a. They are blocked from modulator 657 by band pass filter 651 and by directionality of the coupler, while filter 652 blocks signals from 657 from flowing towards demodulator 656. It is noted that band pass filter 658, 652 and coupler 651 perform filtering and signal separation that is equivalent to that performed by signal separator 613a.

Demodulator 656 converts the received signals to digital logic form. Finally, this data is applied to the NIC card in the same manner that a PC would pass signals to that card. This completes the communication circuit in the wiring closet because any further transmission of the signals is accomplished according to common Ethernet standards.

As described above, modem 645a communicates, in the preferred embodiment, with the tenant's PC through a common parallel port. An advantage of using the parallel port can be seen by envisioning modem 650a and modem 645 working together in a common enclosure. Modem 650a connects to a common 10Base2 Ethernet network, and modem 645a connects to a parallel port on a PC. As such, the combination of the two devices is equivalent to what are known as "pocket Ethernet Adapters." Those devices are small electronic boxes that connect to a parallel port on a PC and also to an Ethernet. As a result of the similarly of the inputs and outputs, modem 645 can be designed to emulate these adapters, and the same software

used to drive the adapters can be used to accommodate the system described herein.

System 2 - Using a PC Bus and Software for Routing.

FIG. 10b shows Hub 618b, which is an alternative to Hub 618a. Like hub 618a, hub 618b includes one modem (shown in FIG. 10b as modem 650b) for each subscribing tenant. Hub 618b also includes bridge transceiver 609a. The main difference between the two is embodied in the way data from bridge transceiver 609a reaches the input of each modem. This mechanism is now described.

Referring to FIG. 10b, data from the Internet reaches bridge transceiver 609a over line 602, and continues on to microprocessing unit (MPU) 670. Data destined for the Internet transmits in the opposite direction. In the preferred embodiment, the physical connection between bridge transceiver 609a and MPU 670 adheres to the Ethernet 10Base2 LAN standard, and the protocols of communication also adhere to standards established for Ethernet LANs. Other types communication links may also suffice.

It is noted that a second bridge transceiver can simply connect to the 10Base2 LAN in the ordinary manner. This will double the data rate between the MPU and the Internet. If more bridge transceivers connect in this manner, the factor limiting the data rate in the wiring closet may ultimately become the 10 Mbs of the 10Base2 link, rather than the aggregate data rate of bridge transceivers.

In the preferred embodiment, data reaching MPU 670 includes a tag that determines which of the tenants is targeted as the final destination. Using software, MPU 670 must interpret this tag, and apply the associated signals onto logical data bus 681 in such a way as to direct them to the appropriate destination. Circuitry that implements such a communication bus is well known.

Furthermore, a particular MPU, Motorola xxx, is already designed to conduct the type of communication described herein, adding an economy to this system.

Modems 650b connect to bus 681 and allow data to flow in each direction. This exchange of data is managed by digital diplexer 684. That device is similar in function to digital diplexer 637, described above.

The function of modems 650b is nearly identical to modems 650a. Both exchange data with the communication bus, and relay that data to the modems in the tenants apartments. As can be seen from Figs 10a and 10b, both use the same arrangement of modulators and passive filtering and coupling to create the data-over-voice function.

One difference in function is that modem 650b must include hardware to recognize data addresses. That function is performed by NIC 653 under control of MPU 654. When modems 650b are used, this function is performed in software by MPU 670.

<u>Connecting Small Offices that are Located in the Building.</u>

The system described herein gives each subscriber shared access to a high capacity line. This capability can be useful for individual residents in an apartment building, but it can also by attractive to small businesses. In particular, when many different small businesses share a common building, some may find that the cost for level of service provided by this system is one that is attractive to them. These businesses may choose to subscribe and locate modem 645a on the desktops of workers with a requirement to access the Internet.

To be sure, a common PBX switch is installed in many such offices, and this device may interrupt the continuity of a twisted pair path reaching between the basement wiring and a desktop. A high frequency bypass

is required to reach the desktop in such a configuration. (This bypass is not shown in this application, but an example is shown in figure 5 of Patent No. 5,010,399.)

Many such offices, however, have a LAN that connects the computers used by several of the workers, and may desire to provide the workers with access to line 602 over this LAN. This can be accomplished by connecting the office LAN to the 10Base2 network in the basement by using a network bridge, such as the bridges described above.

A network bridge can be implemented by a variety of products. Some of the products, such as the V.35 bridges that appear in the catalog of the Black Box Corporation, consist of transceiver pairs. Such a connection is shown in FIG. 10a, where Ethernet Bridge transceiver 659 connects to the Ethernet LAN established in the basement, and the companion transceiver connects to the network LAN established in the office. When such a connection is made, the networks become Ethernet segments relative to each other.

Privacy issues are solved automatically. Data destined for the tenants does not reach the office LAN because bridge 659, which follows Ethernet standards, does not allow traffic for other destinations to flow onto the connected segment. Data destined for the office LAN cannot be intercepted by the tenants because the NIC cards are set to block data that is not tagged for transmission to the tenant. Data destined for the Internet (via high capacity line 602) will be blocked from both the tenants and the office LAN by the same provisions.

<u>The Capacity of the Apartment Internet System</u>

One benefit of connecting computers as described earlier is that each computer can communicate digital data with any other computer in the building. A more

important benefit, which is the focus of this invention, is that each tenant can communicate with the well-known Internet at a relatively high data rate.

There are two data rates internal to the system disclosed herein that will have a big affect on the rate experienced by the users. The first is the rate at which signals communicate from the Internet Connection to hubs 618', 618a, or 618b, located in the wiring closet. The second is the rate at which signals communicate between these hubs and modems 645a (or 645b) in the apartment units.

The proper rates for these links will depend on many factors. There are several characteristics of this system, however, that are common to all implementations, and can help in determining the optimal data rate. Some of these characteristics are described below.

When line 602 communicates at 2 Mbs, there is no immediate reason for modems 650 and modems 645, which determine the data rate internal to the building, to communicate at a higher speed. Valid reasons for implementing a higher data rate are a) to allow for future expansion, b) economy -- some higher data rate devices, such as Ethernet devices, are actually less expensive, and c) the ability to use the link for compressed digital video.

Because of the Internet's "stop-start" nature, a shared connection functions most efficiently when a large part of its capacity can be focused, that is "burst" upon a single user. When the connecting link can focus in this manner, a request for bandwidth can be quickly satisfied and the user examines the data while the bandwidth of the connection is dedicated to satisfying requests of other users in the pool. Until the requests for a "burst" are so numerous as to overlap and concentrate at a single moment in time, every user feels

as if he or she enjoys the full bandwidth of the connecting link.

The data rate of the connection to the Internet is limited by remote bridge 609a, which, in the preferred embodiment, provides a data rate of approximately 2 Mbs. Extra bridges can be added to create a simple increase in this data rate, that is doubling the number of bridges increases the rate of connection to the Internet by a factor of 2.

Many experts believe that the most common experience of an Internet user will be one that proceeds according to this sequence: a) the Internet "refreshes the user's screen," b) the user examines the screen, c) the user makes certain decisions, d) the Internet reacts by refreshing to create a new screen, and e) the cycle begins again. When the newly created screen consists largely of graphics rather than text (alphanumerics) refresh of the screen can be very time consuming. It is this phenomenon that has created a large demand for an increase in the rate at which users can access the Internet.

Using compression methods, approximately 1 million bits are required to fill a computer screen. Meanwhile, the tenant must, presumably, inspect each screen for at least a number of seconds. Because 2 Mbs can refresh a screen in approximately .5 seconds, a doubling in capacity will lower the "wait" time by .25 seconds, which will lower the "advance" from one screen to another by only a small fraction. While there are other uses for the Internet that do not involve advancing from screen to screen, this particular type of use is very common, so an increase in data rate may not be significantly appreciated.

Because a user advancing through screens draws data from the shared line for only a few seconds each

minute, several users can be added before even a very small decrease in service is perceived by the existing users. Also, only a fraction of the total number of subscribing tenants may be actively using the system at any given time.

As a result of the foregoing, it is suggested that 2 Mbs is sufficient until the number of subscribing tenants in the building exceeds between 25-50. A second bridge should be added when the number increases beyond that.

It can be shown, mathematically, that the efficiency of the system increases when the number of users sharing access increases while the "quality of service" remains the same. For example, let the "quality of service" be defined by the percentage of times that a user who requests y seconds of access must wait more than x seconds for such access, (where x is a fixed threshold.) Under those conditions, a doubling of capacity, that is bandwidth, results in an increase in the maximum number of users (that can enjoy at least the same "quality of service") by a factor well above 2 and possibly approaching 4. In other words, the efficiency of bandwidth sharing has increased.

Standard motion pictures can be expressed as a compressed digital Bitstream with a data rate of 1.5 Mbs, and a data rate of 6 Mbs can be used to express any NTSC video signal whatsoever. Transmission of compressed digital video signals, however, requires the source to feed a steady stream of data to the receiver, and such a capability cannot typically be provided by the systems in Figs 6-10. The next section describes how to make the communication link between modems 650 and modems 645 provide a path for the digital video signals generated by the systems disclosed in U.S. patent application Serial No. 08/816,059.

Providing Multiple Apartment Buildings with Shared Access and a Common Router

As described above, when one the systems described in Figs 6-10 is installed in a given apartment building, it creates a LAN among the computers of the tenants in that building. In the preferred embodiment, this network follows the well-known Ethernet LAN standards. (In FIG. 8b, to be precise, only a small Ethernet LAN connects at the root of the electronics -- that is between bridge transceiver 609a and MPU 670. Data moving beyond MPU 670 to the individual tenants is shared by means other than LAN technology.)

According to these standards, many such networks can be connected to a master network using devices known as Ethernet bridges. The result is that all the computers in all the buildings are actually part of the same large network. (The LAN in the basement of a single building is referred to as an "Ethernet segment," and the larger network is composed of many of these different segments.)

A device called a router is required to provide Internet access to the computers on an Ethernet network. One router can suffice for each network, even networks that are composed of many different segments. Because routers are relatively expensive, there is a significant advantage to connecting (the networks installed in) several buildings so that they become separate Ethernet segments of a single common network, allowing one router to serve them all.

Another economy available to large networks is the shared use of a computer called an Internet workstation. Such a computer can be useful in improving the convenience and power available to users accessing the Internet over a network. A single computer,

moreover, can be useful to any of the users on any segment of the network.

A system of connecting the network segments installed in multiple apartment buildings is now described. In addition to the economy of a single router and a single Internet workstation, this system will enjoy the added advantage, described above, of having all segments share the same connection into the Ethernet. (This advantage was described earlier in terms of several individual users sharing access to the same high-speed line. The same principles apply when several network segments share the same port of access.)

Referring to FIG. 11, a group of bridge transceivers 609b are located together with router 672 and port 670. Port 670 is a port providing a fixed rate of access into the Internet. It connects to router 672, which connects to bus 675, which is a simple 10Base2 Ethernet bus. The bridge transceivers 609b also connect to the same bus. Bridge transceivers 609b and router 672 are co-located with port 670. Such a location is commonly referred to as a "point of presence."

Internet workstation 686a and PSTN 686b also connect to this bus. The workstation provides the economy described above. PSTN Link 686b communicates with PBX/Voice Concentrator 698a, shown in FIG. 9a. Those devices cooperate to connect the telephones in each apartment (of the group of apartments) to a common port of the public switched telephone network.

The connections described above establish a network among router 672, the transceivers 609b, the Internet workstation and the PSTN link. 10 Mbs can flow across this network when common Ethernet standards are used. Data flows between the Internet and this network via port 670 and router 672. Router 672 processes the data as it is applied to the network. It follows well

established protocols for communicating between Ethernet networks and the Internet. In particular, it examines the addressing information associated with the data, and alters that information so that it can be understood by the bridges and the network interface cards (also known as network adapters,) that are connected to the network.

A group of apartment buildings is shown at the top of FIG. 11. Bridge transceiver 609a is installed in the basement of each of these buildings, as well as the other electronics shown in Figs 9-10. At the point of presence, each of transceivers 609b is the dedicated companion of one of bridge transceivers 609b installed in the basement of one of the apartment buildings. (More than one of bridge transceivers 609a may be connected to the network segment in the basement wiring closet of any given building, so long as it has a dedicated companion transceiver at the point of presence. Systems where the transceivers are not pairwise dedicated are also possible.) The link between each transceiver pair connects the network in the corresponding building together with the network at the point of presence, making the network in the building an individual "segment" of this larger network. The following results are now established:

Any piece of data sent from port 670 is processed by router 672. After processing, the data will be targeted for one of the tenants in one of the buildings. (In the system described in FIG. 10b, router 672 directs data only so far as the correct buildings. Routing performed by MPU 670 computes the final address that is used to direct the data to the correct tenant.)

This data will be input by the one of Ethernet transceivers 609b that connects to the LAN at the point of presence. The data will be passed across to the

companion Ethernet transceiver 609a. It will not flow to other buildings.

The Ethernet transceiver 609a will apply the data to the access sharing system inside the building. The data will be recognized by hub 618' (or by modem 650a or modem 650b) and directed to the correct tenant.

Data transmitted from a tenant and destined for the Internet will be interpreted by the bridge transceiver 609a in the building of that tenant. This data will be relayed back to the point of presence, where it will be received by the companion bridge transceiver 609b. It will then flow across bus 675 to router 672, where its address will be processed and passed to the Internet through port 670.

In the preferred embodiment, data will flow from the Internet, through port 670, through the router, onto the bus 675 and will be received by one of bridge transceivers 609b. This data will flow at a rate of 10 Mbs. Data will flow between bridge transceivers 609b and 609a at a rate of 2 Mbs, and these bridges follow the BestLAN system, referenced above. (The aggregate data rate reaching a building can be increased by providing extra bridging.) The considerations governing the rates at which data flow internal to the buildings were discussed earlier.

Assuming there are 10 buildings, if each building connected directly to the Internet, rather than through a shared connection, its demands could be completely satisfied by a dedicated 2 Mbs connection. In that situation, 10 buildings would require at most 20Mbs of access. Because of the efficiency, described above, where several network segments share the same port of access, a port of significantly less than 20Mbs will provide exactly the same level of service as would be provided if each segment enjoyed the dedicated 2 Mbs

connection. Assuming, as before, between 25-50 subscribers for each 2 Mbs connection, implies that approximately 400 subscribers could feel they enjoy a 2 Mbs access from a port whose capacity is less than 20Mbs. These numbers translate to 50 Kbs per customer, indicating that shared access provides a very substantial efficiency.

When there are only a very small number of subscribers in an apartment building, one may not be able to justify the cost of dedicating bridge transceivers 609a and 609b to such a building. In this case, the network segment established by transceiver 609a can be broadened by connecting extra buildings. In particular, a bridge can connect the network segment in the "under-subscribed" building to a neighboring building. If the neighboring building is nearby, the cost of the bridge may be significantly less than the cost of the 609 pair, and total number of subscribers in the two buildings can justify the cost of the link to the Point of Presence. This type of "doubling" is illustrated by the apartment building shown in the upper left of FIG. 11.

Providing for Transmission of Digital Video

Recent advances in compressed digital video have increased the number of video signals that reach subscribers in digital form. In particular, signals received by 18-inch satellite dishes, called DSS signals, are received in this form, and the US telephone companies have announced plans to deliver their programming in digital form via microwave technology.

In U.S. patent application Serial No. 08/816,059, many methods were described for allowing tenants in apartment buildings to access video sources, that provide many programs brought to the basement wiring closet via one or more hi-capacity paths. Using these systems, tenants would send a control signal down to the

electronics in the wiring closet. This signal would indicate which of the programs should be sent to the tenant's apartment unit, and the basement electronics would respond accordingly. Part of the system that brought the signals to the tenants required, of course, a digital link between the basement and the apartment unit up above.

In this invention, such digital links are provided between modem 650a and modem 645a. To use these links to communicate compressed digital video, however, a mechanism of transmitting the data streams to modem 650a must be provided. Applying these signals directly to the network established by bus 619 is not a solution because the network cannot guarantee transmission of a datastream at a minimum steady rate, a characteristic required for digital video transmission.

Referring to FIG. 10a, it is seen that two communication lines connect to FIFO 655: the line connecting to NIC 653, and a line from digital video source 655a. Source 655a can be provided, in coordination with a path for control signals, by many of the systems described in U.S. patent application Serial No. 08/816,059. MPU 654 controls FIFO 655, enabling it to input digital signals from either NIC 653 or source 655a. If digital signals are input from the video source rather than NIC 653, there is no reason for interruptions of the datastream, and the digital signals can flow steadily to the PC up in the tenant's apartment. Electronic hardware is available, such as the well-known MPEG hardware, that can provide a PC with the capability of displaying compressed digital video on common PC monitors.

<u>A Transmit/Receive Pair that can Communicate either Data or Analog Video</u>

U.S. patent application Serial No. 08/816,059 described circuitry for transmitting analog video signals over twisted pair wiring using FM methods. As described therein, these signals can communicate over a single twisted pair wire at the same time as digital signals, so long as different frequency bands are used for each. In configurations where two twisted pairs serve the end user, FM video can transmit over one pair and digital signals over the second.

Because of the recent and very large increase in interest in communications, there has been an increase in the demand for new paths that bring data and/or video to end users. When communicating over internal telephone wiring according to the methods disclosed in this application and its predecessors, transmission over the final link reaching the end user typically requires a different transmit/receive pair for each type of signal. As a result, an efficiency can be obtained when one transmit/receiver pair can manage communication of signals of two or more different types.

A method is now disclosed for a transmit/receive pair that can communicate both analog video and digital signals. The transmit/receive pair works on FM principles. Conceptually, an FM transmit/receive pair will treat any input waveform in the same manner -- whatever waveform is input by the transmitter will be reproduced as output at the receive end. The only consideration is that the bandwidth of the input be within the range of the devices.

As a result of the property that FM transmit/receive pairs are essentially transparent to the nature of their input, the same transmit/receive pairs described in U.S. patent application Serial No. 08/431,270 can be used to communicate a digital Bitstream as well as an analog video signal. An example of how

these devices would react to digital and analog input is shown in FIG. 12.

An example of the time varying behavior of an ordinary NTSC video signal, expressed at baseband, is shown in the left most diagram of the top row in FIG. 12. The waveform looks arbitrary, but its spectrum, shown in the diagram to the right, indicates that its energy is confined below 4.5 MHZ. As in classic frequency modulation, the time varying amplitude of the input waveform is used to create time-varying alterations in the frequency of a carrier, shown at the right. This carrier, which oscillates at 25 MHZ when no input is applied, travels over 20 MHZ of spectrum, between 15 MHZ and 35 MHZ, when reacting to the video information supplied at its input. This motion provides an encoded expression of the video information. The FM receiver at the receive end will interpret this motion to reconstruct the signal on the left.

A bi-level square wave produced by digital logic is shown on the left side of the lower row. High levels represent ones and low levels represent zeros. If the data rate is at or below 2 Mbs, most of its spectrum will be confined below 4.5 MHZ, as shown in the middle diagram. In response to the movement between high and low levels, the frequency of the 25 MHZ carrier changes between approximately 17.5 MHZ and 32.5 MHZ. The spectrum of the transmitted signal is shown on the right, concentrated at the 17.5 and 32.5 extremes but spread about them so that the entire spectrum is largely confined to the same channel as is shown in the top row. The motion of the carrier between the two frequency extremes is detected by the receiver and used to reproduce the square wave at the receive end.

The foregoing represents an example of how the same transmit/receive pair can be used to communicate

either a digital Bitstream or an analog video signals, whichever is fed at its input. As a result of this economy, there may be good reason to use such pairs as the components of the digital network described above. They would perform the functions, embodied in modulators 610, 657, and demodulators 636, that expressed the digital bitstreams as waveforms on the wiring, and the reverse.

What is claimed is :

Claims

1. A system of communicating digital information between a source of said digital information and a plurality of a destinations for said source digital information, said system comprising:

a switching hub coupled to said source,

said hub directing information from said source selectively to ones of a plurality n of switch lines as signals in a selected frequency band that exceeds frequencies of voice signals on a telephone link;

a switch coupling each switch line selectively to one of a plurality m of phone lines, of a telephone link, said telephone link carrying voice signals from at least one telephone connected to said link; and

circuitry for controlling the switch, and

where the number of phone lines m exceeds the number of switch lines n.

2. The system of claim 1 wherein said switch is a cross-point switching circuit.

3. The system of claim 1 wherein said plurality of telephone lines connect to various of a plurality of units in an apartment building.

4. The system of claim 3 wherein said plurality of switch lines and said hub are physically positioned in a basement area of said apartment building.

5. The system of claim 1 wherein

said switch lines carry digital data to and from said hub, and

said hub is an Ethernet switching hub.

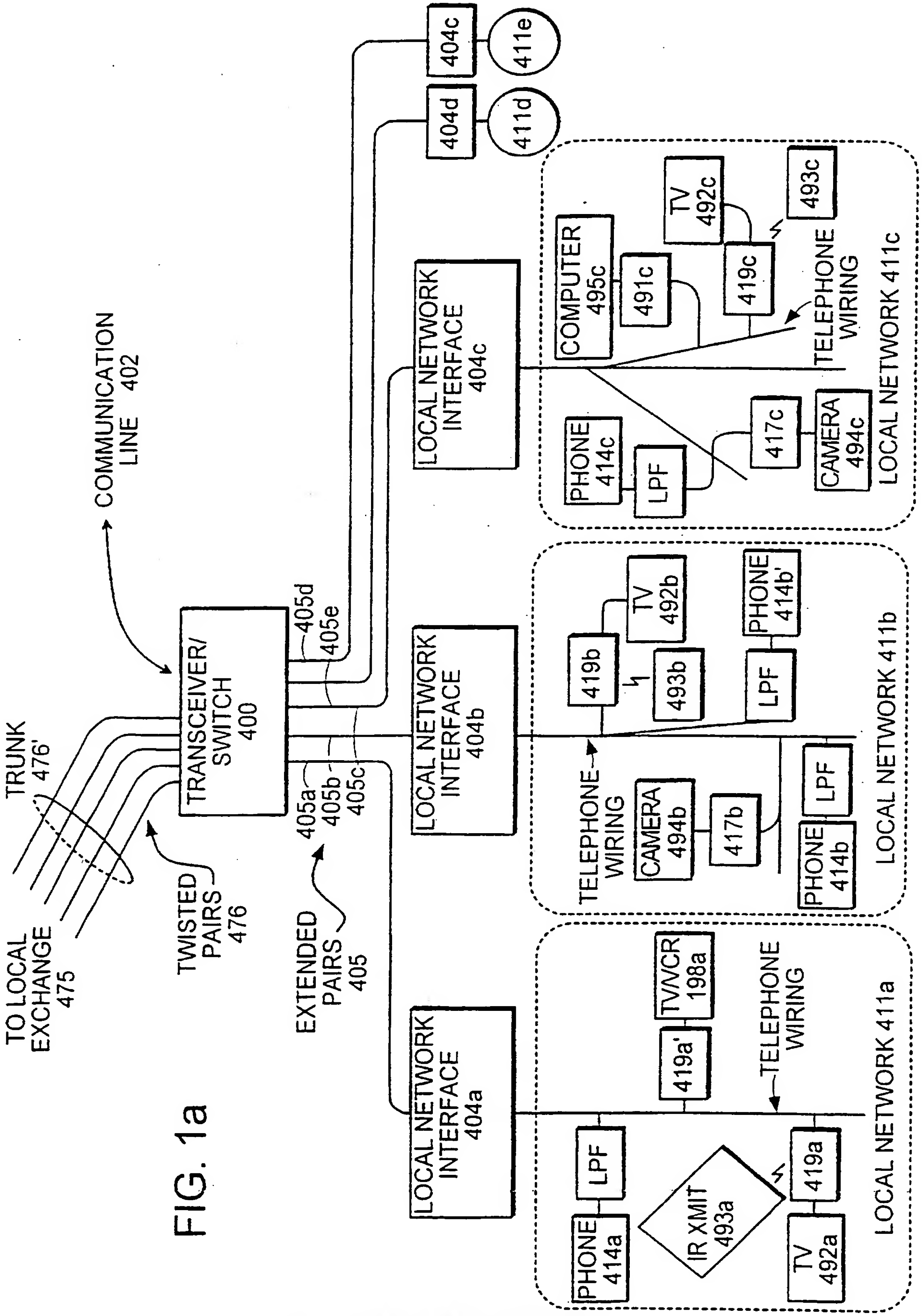

TO LOCAL EXCHANGE 475
TRUNK 476'
TWISTED PAIRS 476
EXTENDED PAIRS 405
COMMUNICATION LINE 402
TRANSCEIVER/ SWITCH 400
405a
405b
405c
405d
405e
LOCAL NETWORK INTERFACE 404a
LOCAL NETWORK INTERFACE 404b
LOCAL NETWORK INTERFACE 404c
404d
404c
411d
411e
PHONE 414a
LPF
IR XMIT 493a
419a
TV 492a
419a'
TV/VCR 198a
TELEPHONE WIRING
LOCAL NETWORK 411a
TELEPHONE WIRING
CAMERA 494b
417b
PHONE 414b
LPF
419b
493b
TV 492b
LPF
PHONE 414b'
LOCAL NETWORK 411b
PHONE 414c
LPF
417c
CAMERA 494c
COMPUTER 495c
491c
419c
TV 492c
493c
TELEPHONE WIRING
LOCAL NETWORK 411c

FIG. 1a

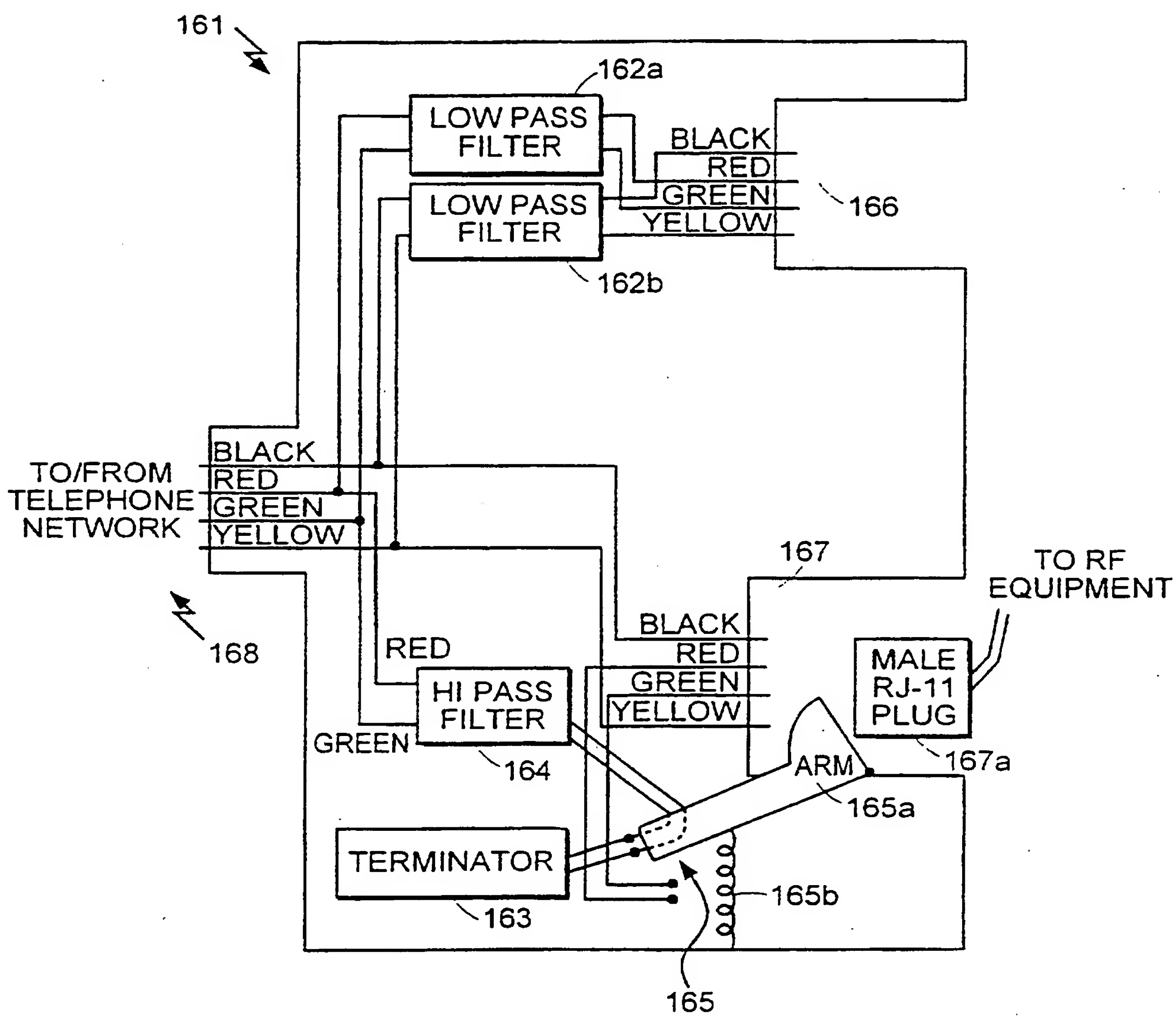

161
162a
LOW PASS FILTER
LOW PASS FILTER
BLACK
RED
GREEN
YELLOW
166
162b
TO/FROM TELEPHONE NETWORK
BLACK
RED
GREEN
YELLOW
167
TO RF EQUIPMENT
168
BLACK
RED
GREEN
YELLOW
RED
HI PASS FILTER
GREEN
164
MALE RJ-11 PLUG
167a
ARM
165a
TERMINATOR
163
165b
165

FIG.1b

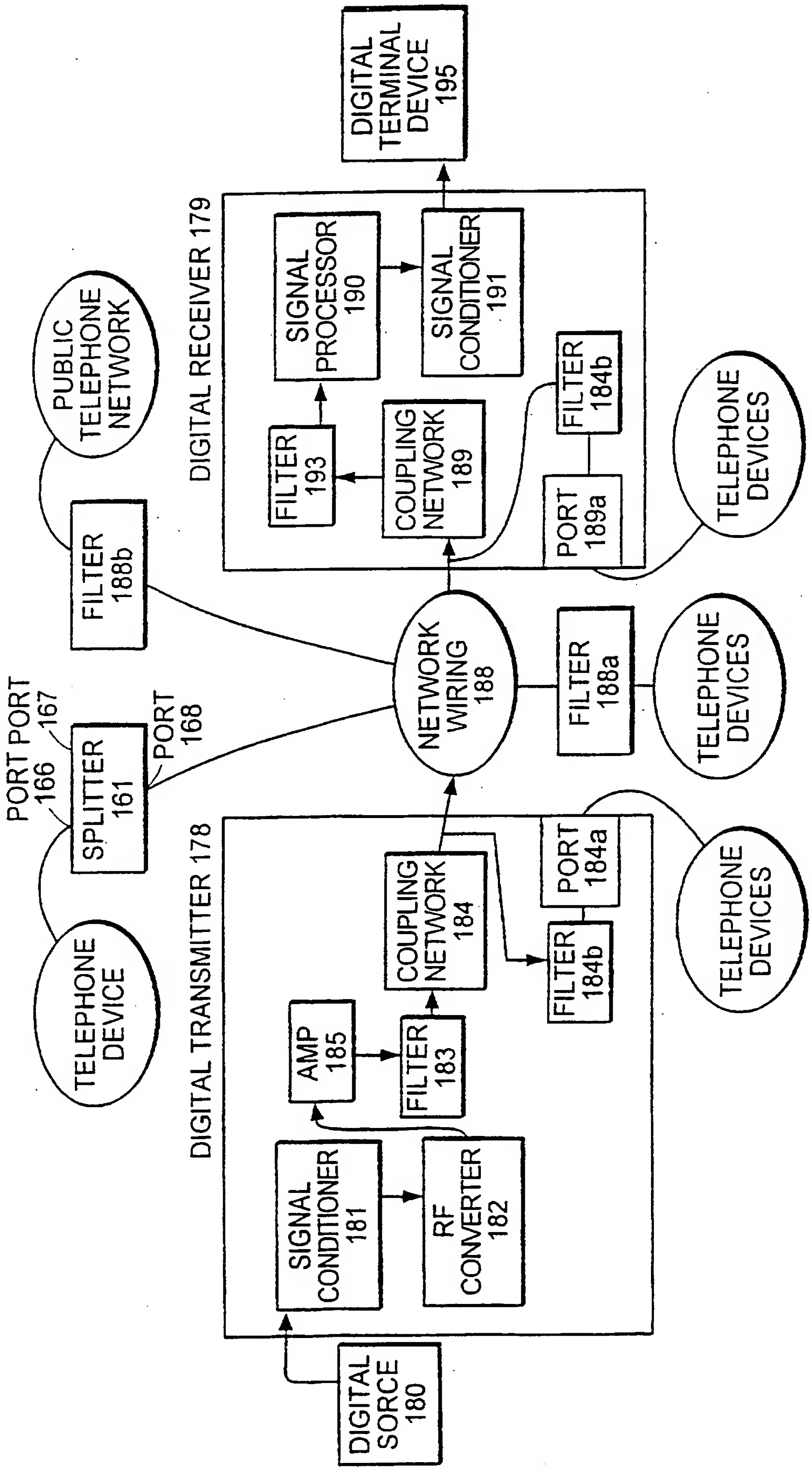

DIGITAL TERMINAL DEVICE 195
DIGITAL RECEIVER 179
SIGNAL PROCESSOR 190
SIGNAL CONDITIONER 191
FILTER 193
COUPLING NETWORK 189
FILTER 184b
PORT 189a
PUBLIC TELEPHONE NETWORK
FILTER 188b
TELEPHONE DEVICES
NETWORK WIRING 188
FILTER 188a
TELEPHONE DEVICES
PORT 166
PORT 167
SPLITTER 161
PORT 168
TELEPHONE DEVICE
DIGITAL TRANSMITTER 178
COUPLING NETWORK 184
PORT 184a
FILTER 184b
TELEPHONE DEVICES
AMP 185
FILTER 183
SIGNAL CONDITIONER 181
RF CONVERTER 182
DIGITAL SORCE 180

FIG. 1c

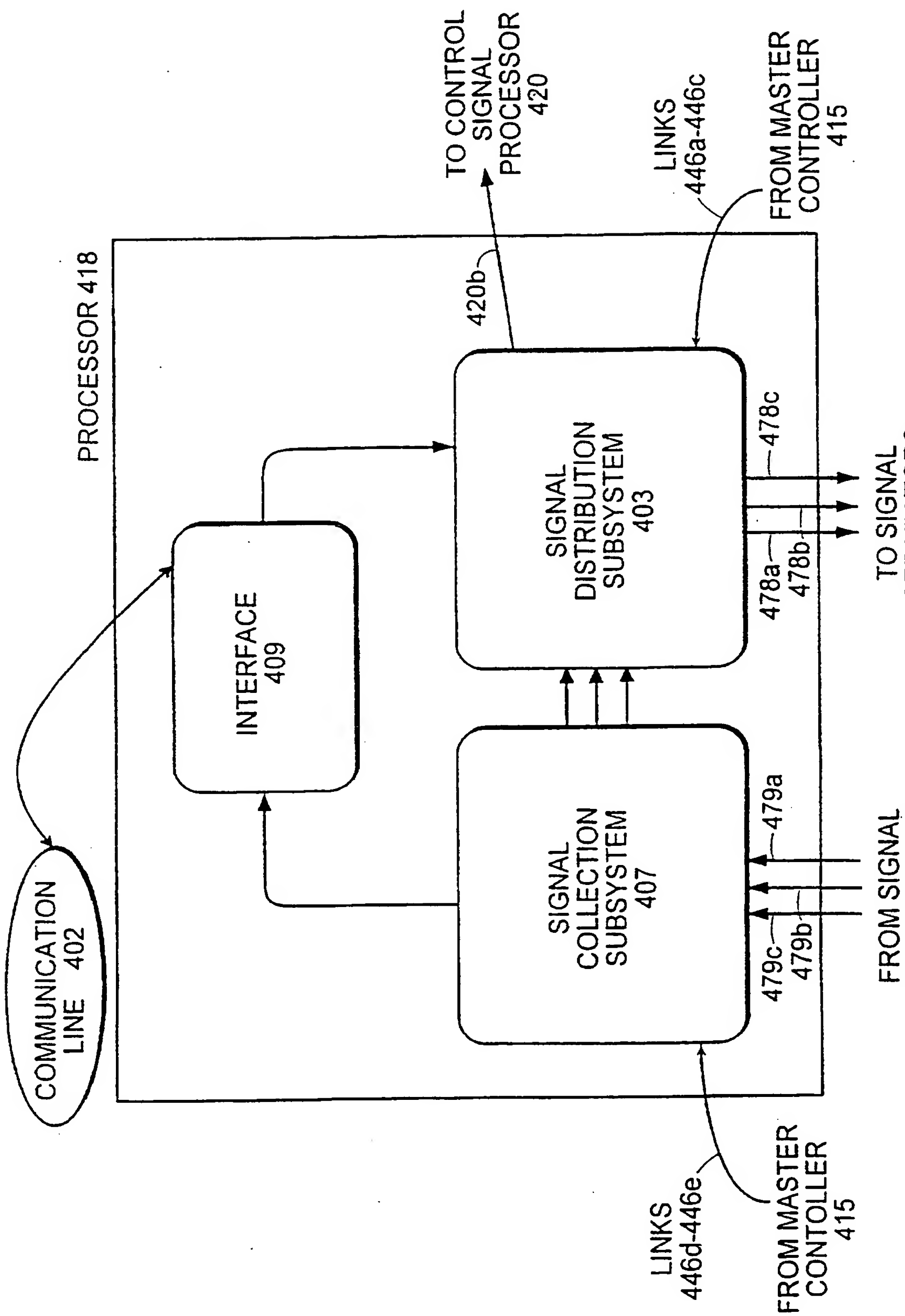

TO CONTROL SIGNAL PROCESSOR 420
LINKS 446a-446c
FROM MASTER CONTROLLER 415
PROCESSOR 418
420b
SIGNAL DISTRIBUTION SUBSYSTEM 403
478c
478a
478b
TO SIGNAL SEPARATORS 413
INTERFACE 409
COMMUNICATION LINE 402
SIGNAL COLLECTION SUBSYSTEM 407
479a
479c
479b
FROM SIGNAL SEPARATORS 413
LINKS 446d-446e
FROM MASTER CONTOLLER 415

FIG. 1d

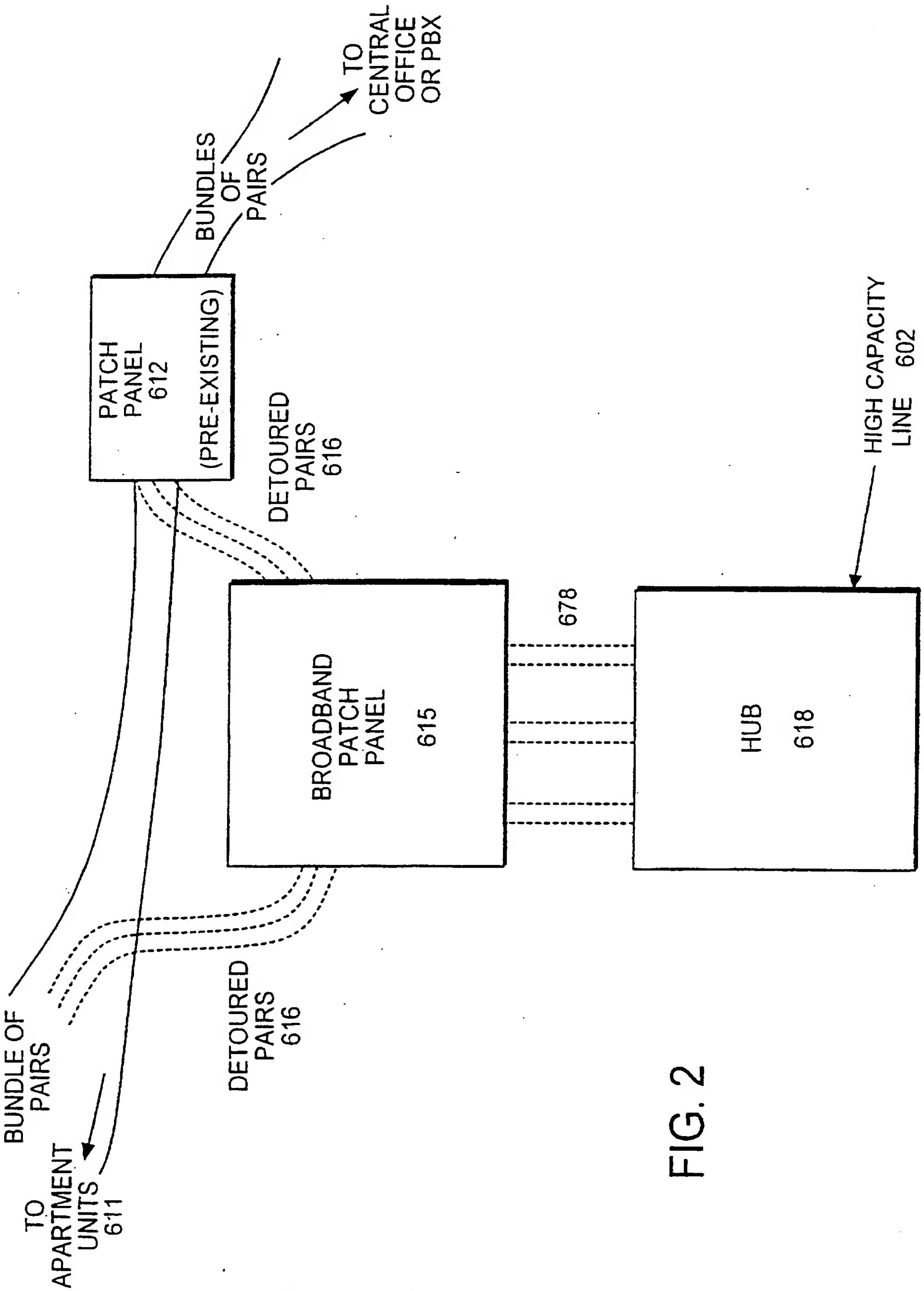

TO CENTRAL OFFICE OR PBX
BUNDLES OF PAIRS
PATCH PANEL 612
(PRE-EXISTING)
DETOURED PAIRS 616
BROADBAND PATCH PANEL 615
678
HUB 618
HIGH CAPACITY LINE 602
DETOURED PAIRS 616
BUNDLE OF PAIRS
TO APARTMENT UNITS 611

FIG. 2

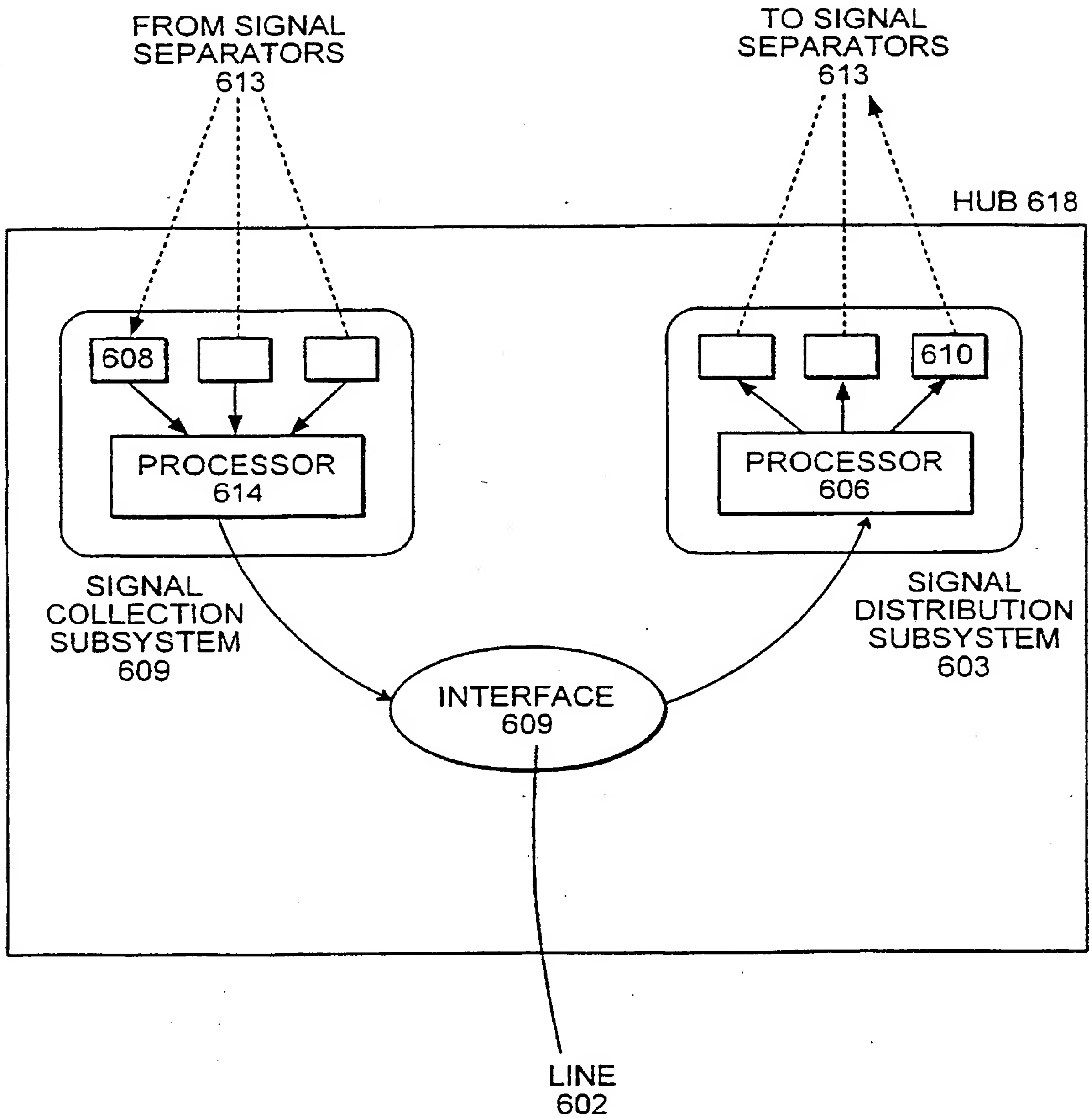
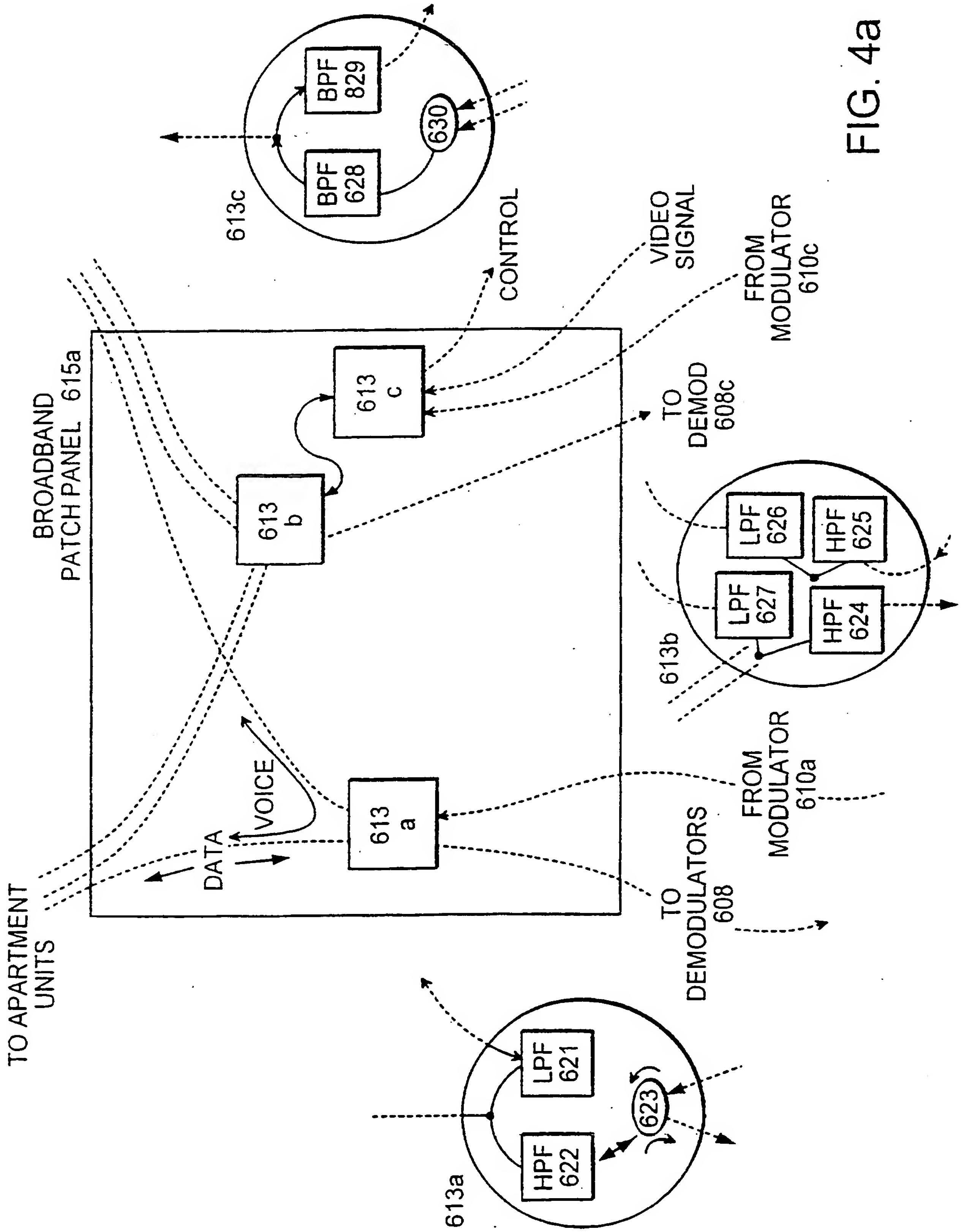

FROM SIGNAL
SEPARATORS
613
TO SIGNAL
SEPARATORS
613
HUB 618
608
610
PROCESSOR
614
PROCESSOR
606
SIGNAL
COLLECTION
SUBSYSTEM
609
SIGNAL
DISTRIBUTION
SUBSYSTEM
603
INTERFACE
609
LINE
602

FIG. 3



613c
BPF 628
BPF 829
630
CONTROL
VIDEO SIGNAL
FROM MODULATOR 610c
BROADBAND PATCH PANEL 615a
613 c
613 b
TO DEMOD 608c
LPF 626
HPF 625
LPF 627
HPF 624
613b
FROM MODULATOR 610a
VOICE
DATA
613 a
TO DEMODULATORS 608
TO APARTMENT UNITS
LPF 621
HPF 622
623
613a

FIG. 4a

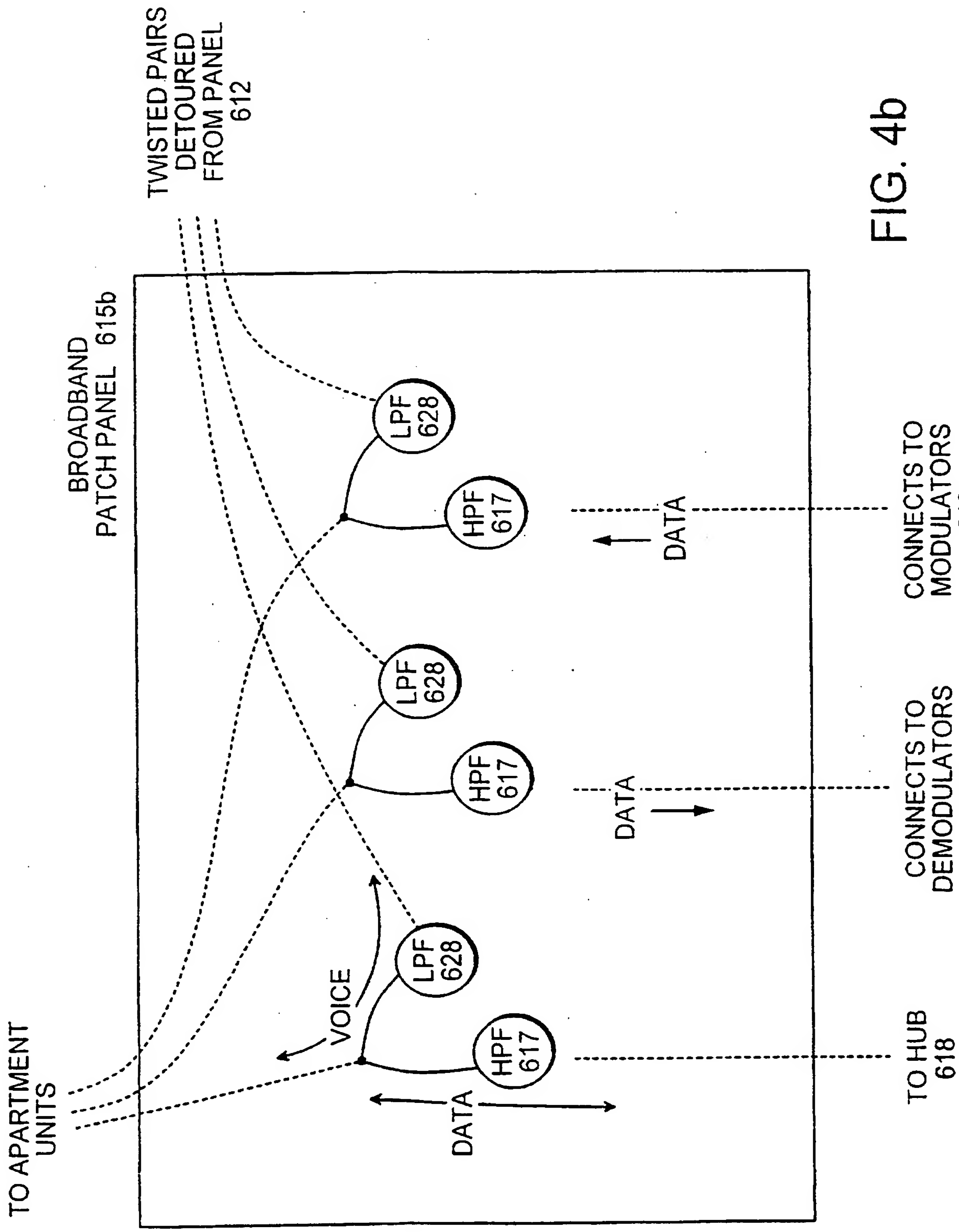

TWISTED PAIRS
DETOURED
FROM PANEL
612
BROADBAND
PATCH PANEL 615b
LPF
628
HPF
617
LPF
628
HPF
617
LPF
628
HPF
617
VOICE
DATA
DATA
DATA
TO APARTMENT
UNITS
CONNECTS TO
MODULATORS
610
CONNECTS TO
DEMODULATORS
608
TO HUB
618

FIG. 4b

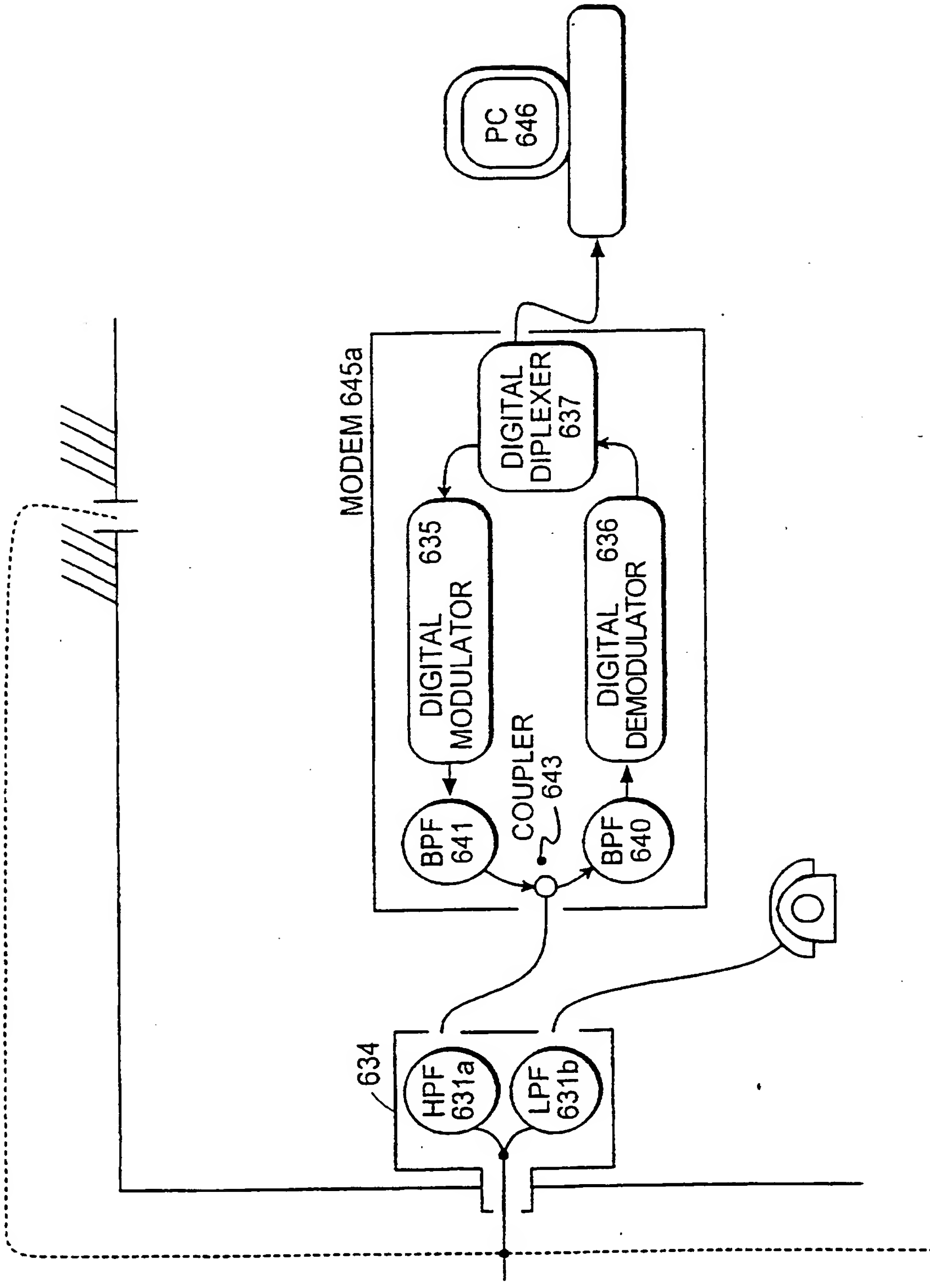

PC
646
MODEM 645a
DIGITAL
DIPLEXER
637
DIGITAL
MODULATOR
635
DIGITAL
DEMODULATOR
636
BPF
641
COUPLER
643
BPF
640
634
HPF
631a
LPF
631b
TO HUB
618

FIG. 5

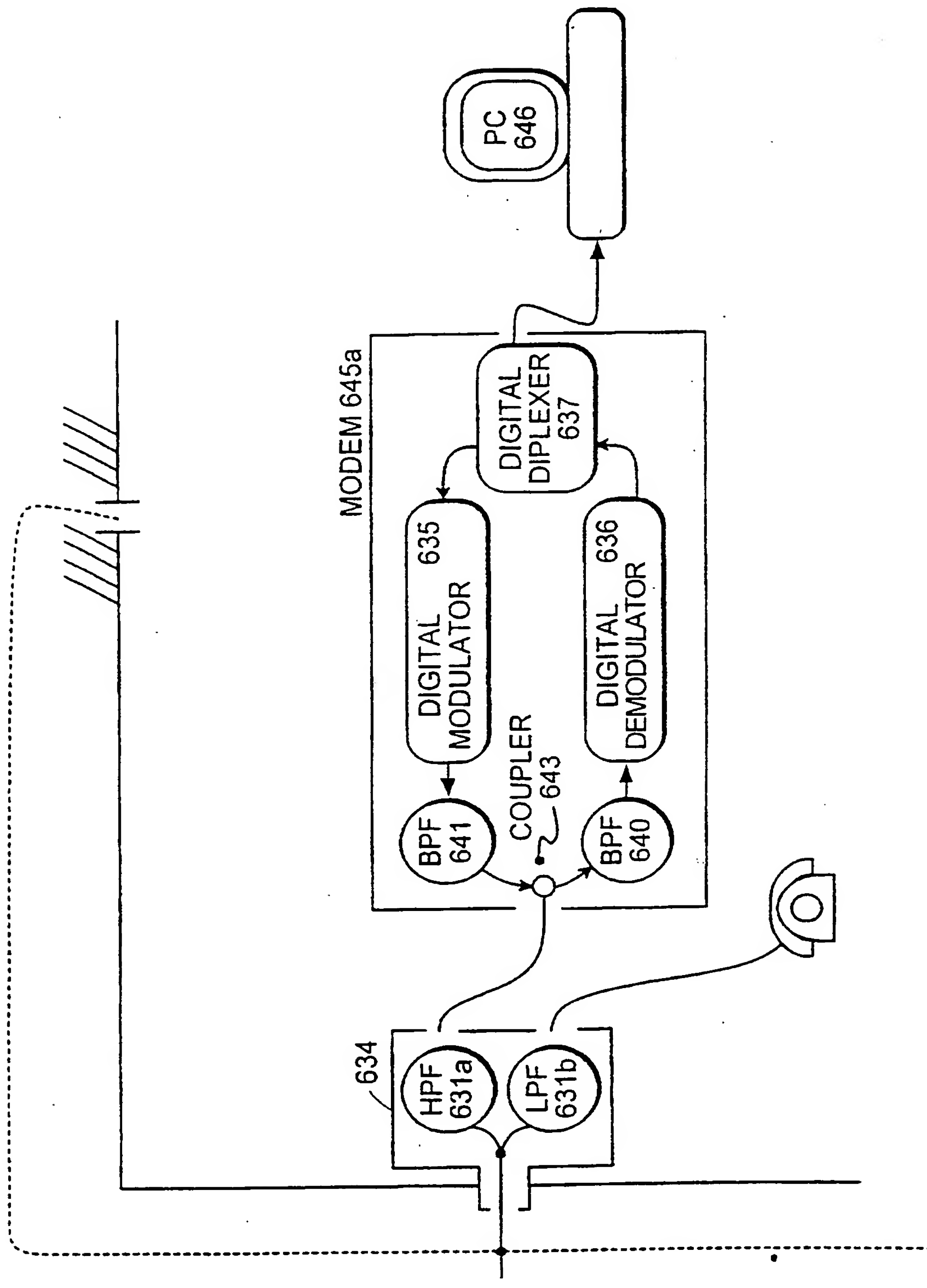

PC
646
MODEM 645a
DIGITAL
DIPLEXER
637
DIGITAL
MODULATOR
635
DIGITAL
DEMODULATOR
636
BPF
641
COUPLER
643
BPF
640
634
HPF
631a
LPF
631b
TO HUB
618

FIG. 5

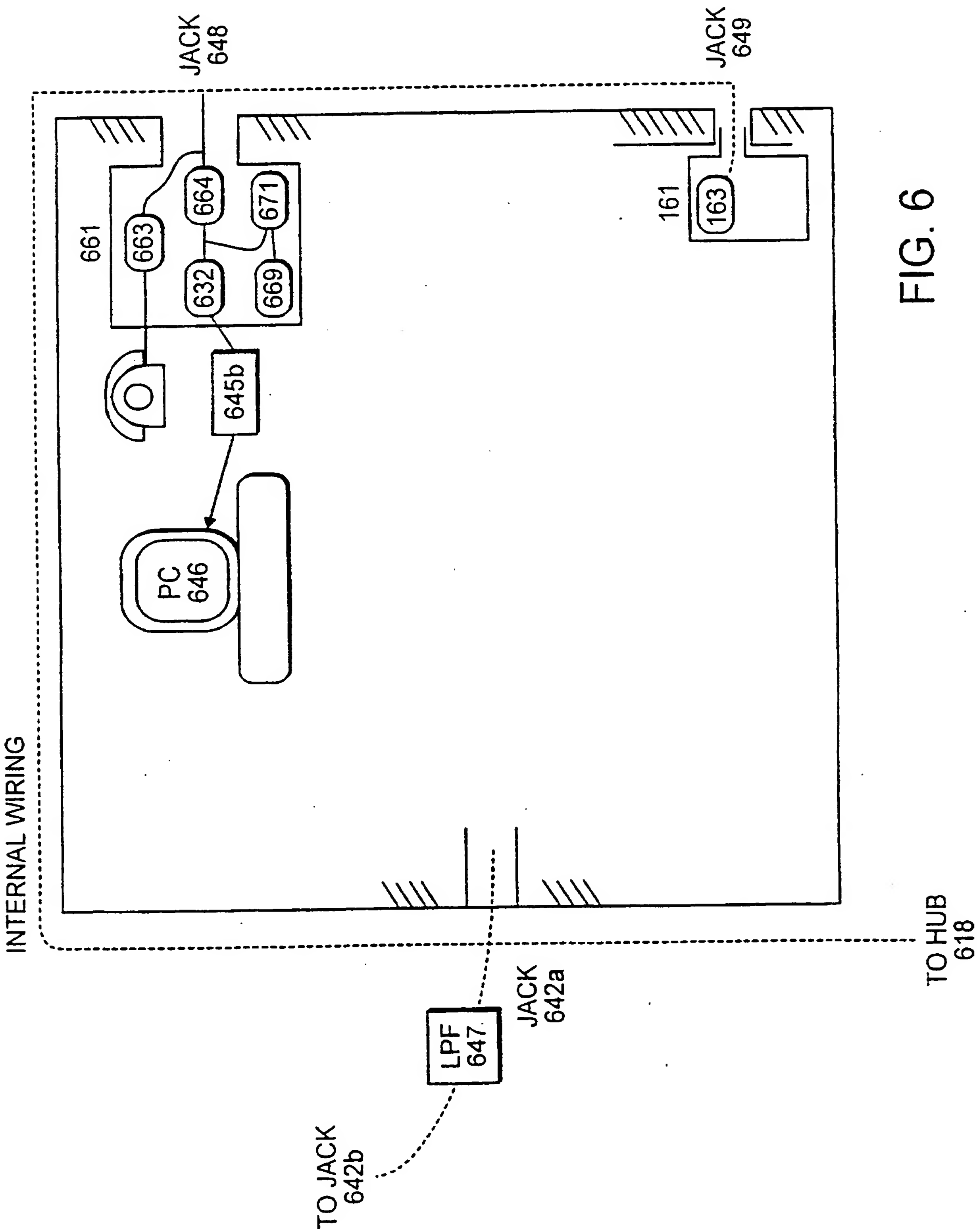

JACK
648
JACK
649
661
663
664
671
632
669
161
163
645b
PC
646
INTERNAL WIRING
TO HUB
618
JACK
642a
LPF
647
TO JACK
642b

FIG. 6

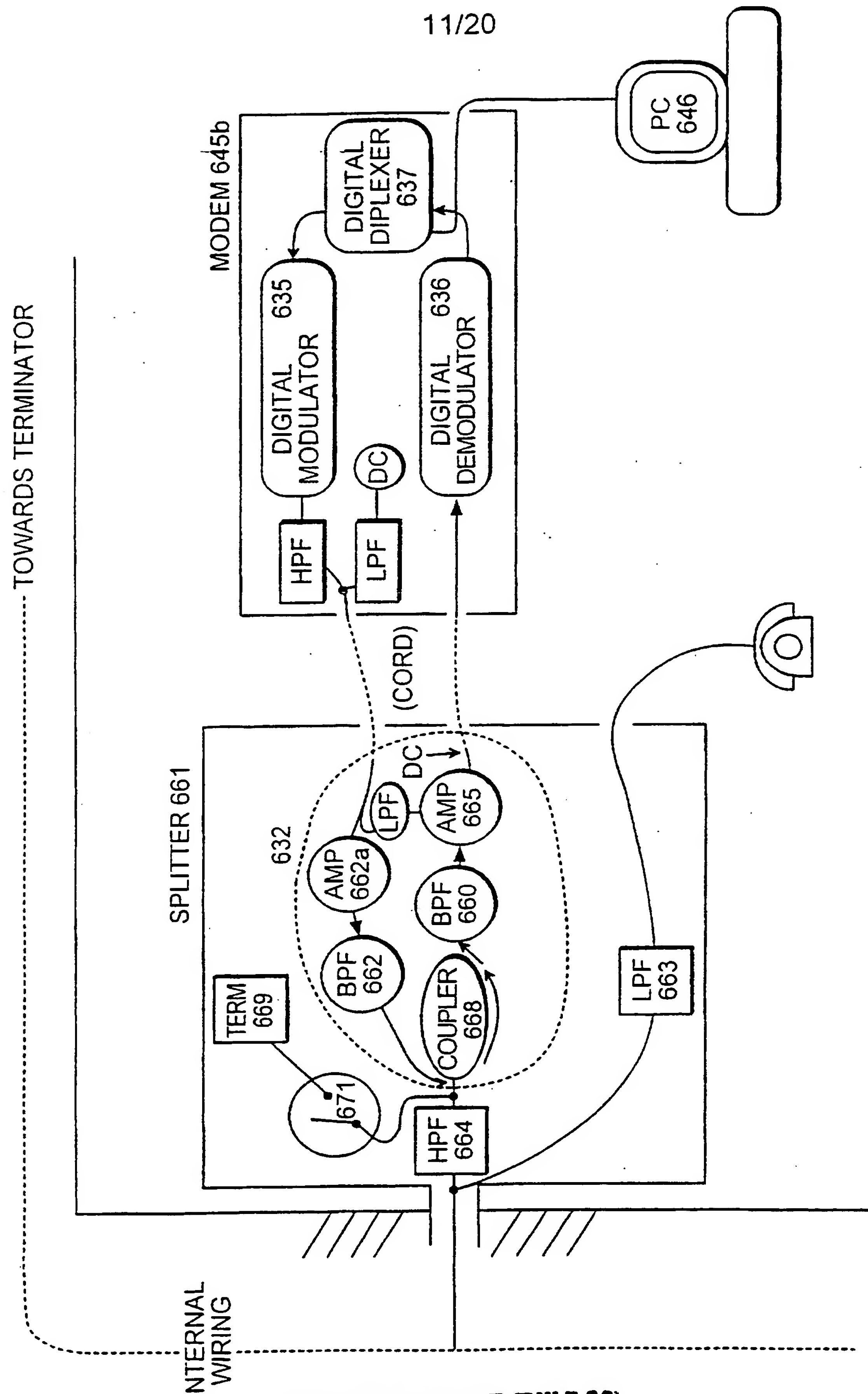

TOWARDS TERMINATOR
MODEM 645b
DIGITAL DIPLEXER 637
PC 646
DIGITAL MODULATOR 635
DIGITAL DEMODULATOR 636
DC
HPF
LPF
(CORD)
SPLITTER 661
632
DC
LPF
AMP 665
AMP 662a
BPF 660
BPF 662
COUPLER 668
TERM 669
671
HPF 664
LPF 663
INTERNAL WIRING
TO HUB 618

FIG. 7

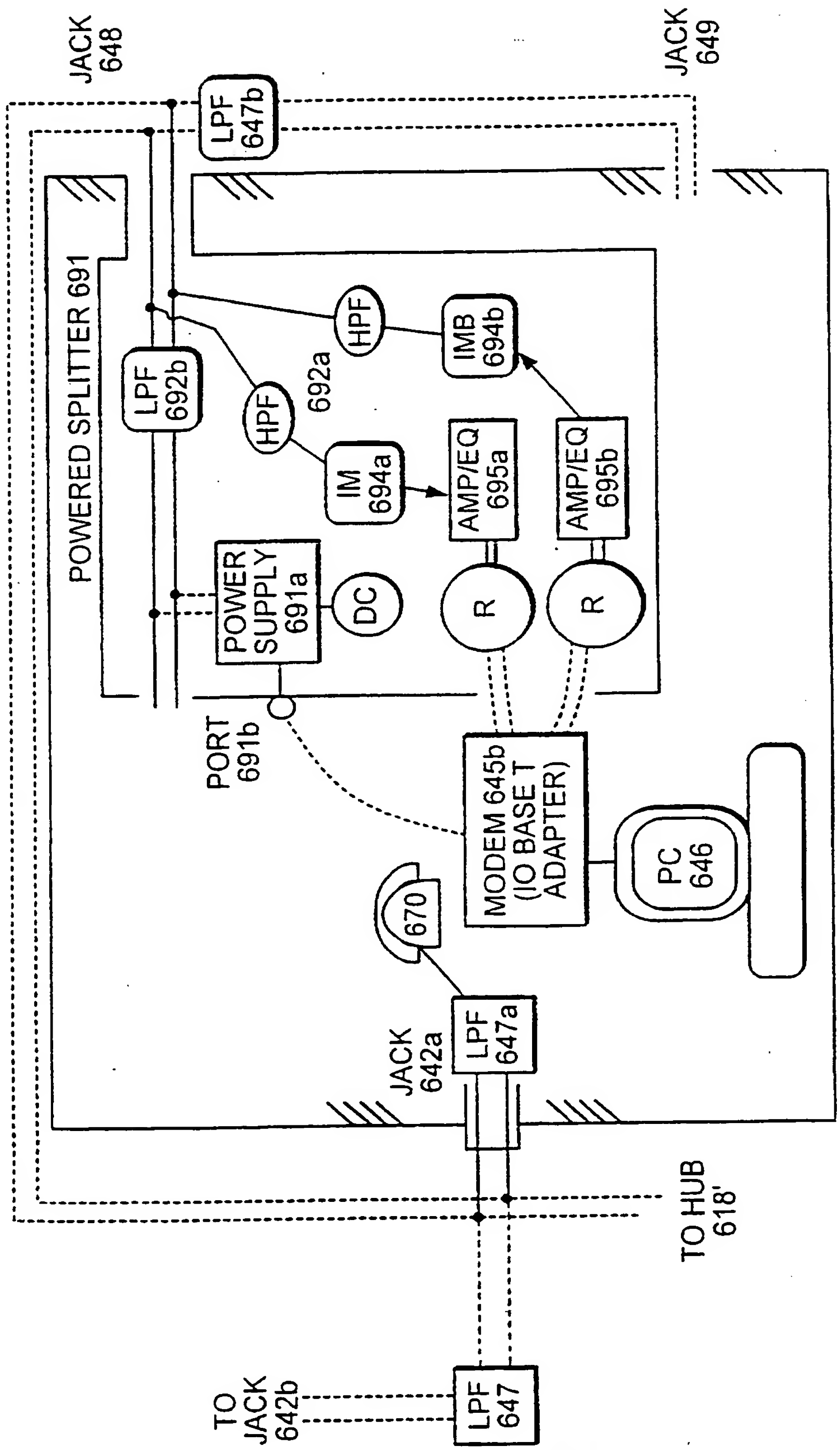

JACK 648
JACK 649
LPF 647b
POWERED SPLITTER 691
LPF 692b
HPF
692a
HPF
IMB 694b
IM 694a
AMP/EQ 695a
AMP/EQ 695b
POWER SUPPLY 691a
DC
R
R
PORT 691b
MODEM 645b (IO BASE T ADAPTER)
PC 646
670
JACK 642a
LPF 647a
TO HUB 618'
TO JACK 642b
LPF 647

FIG. 8a

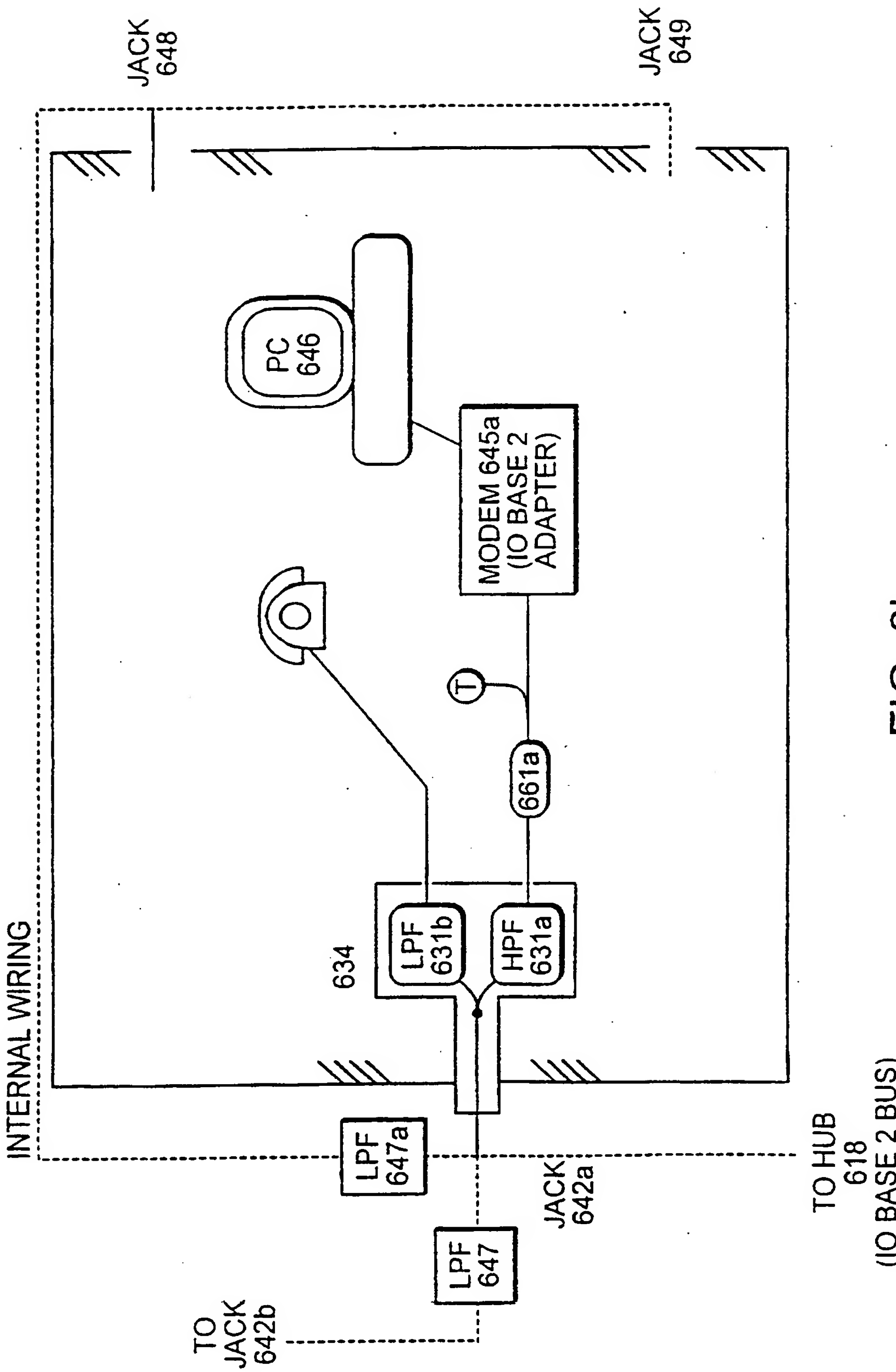
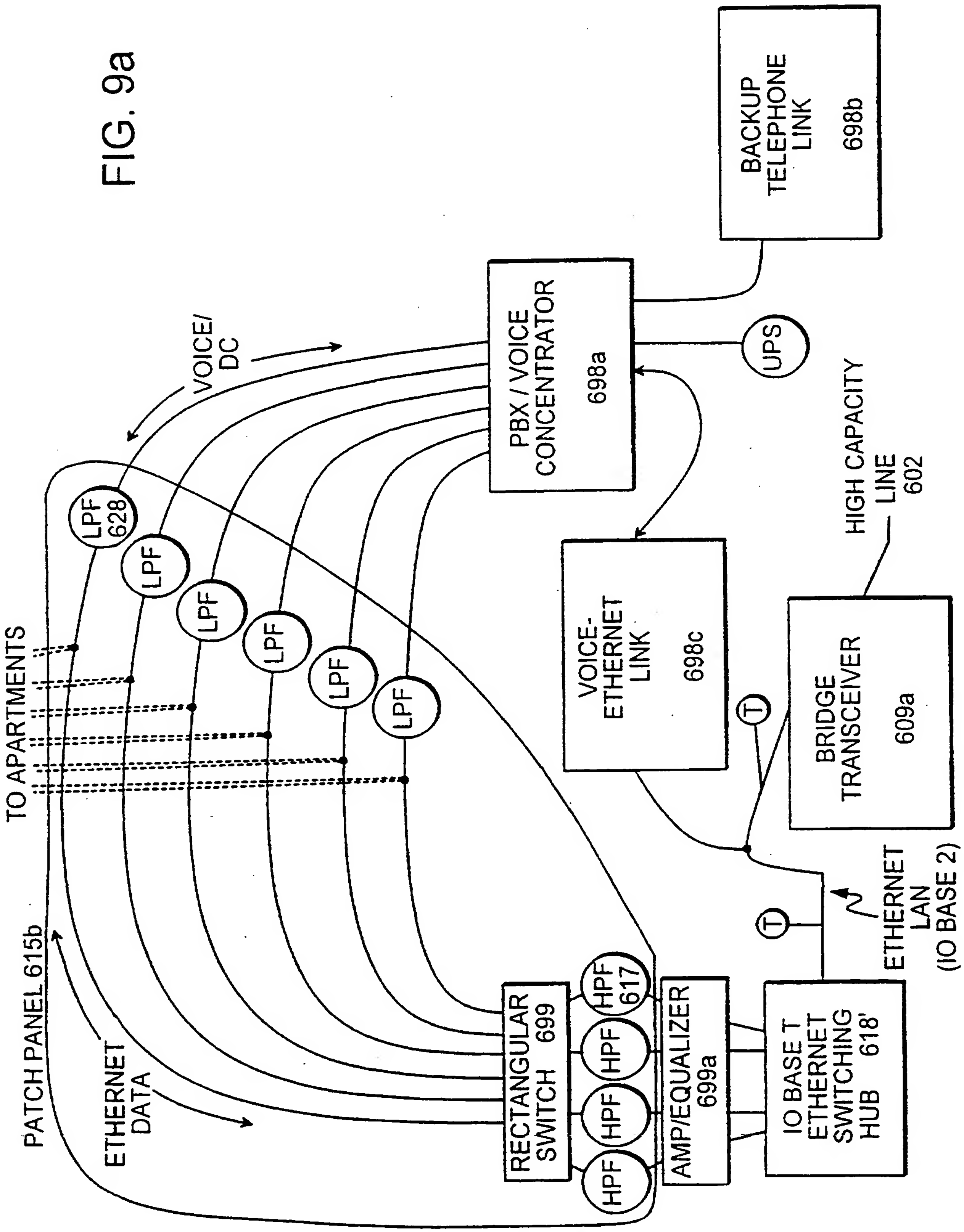
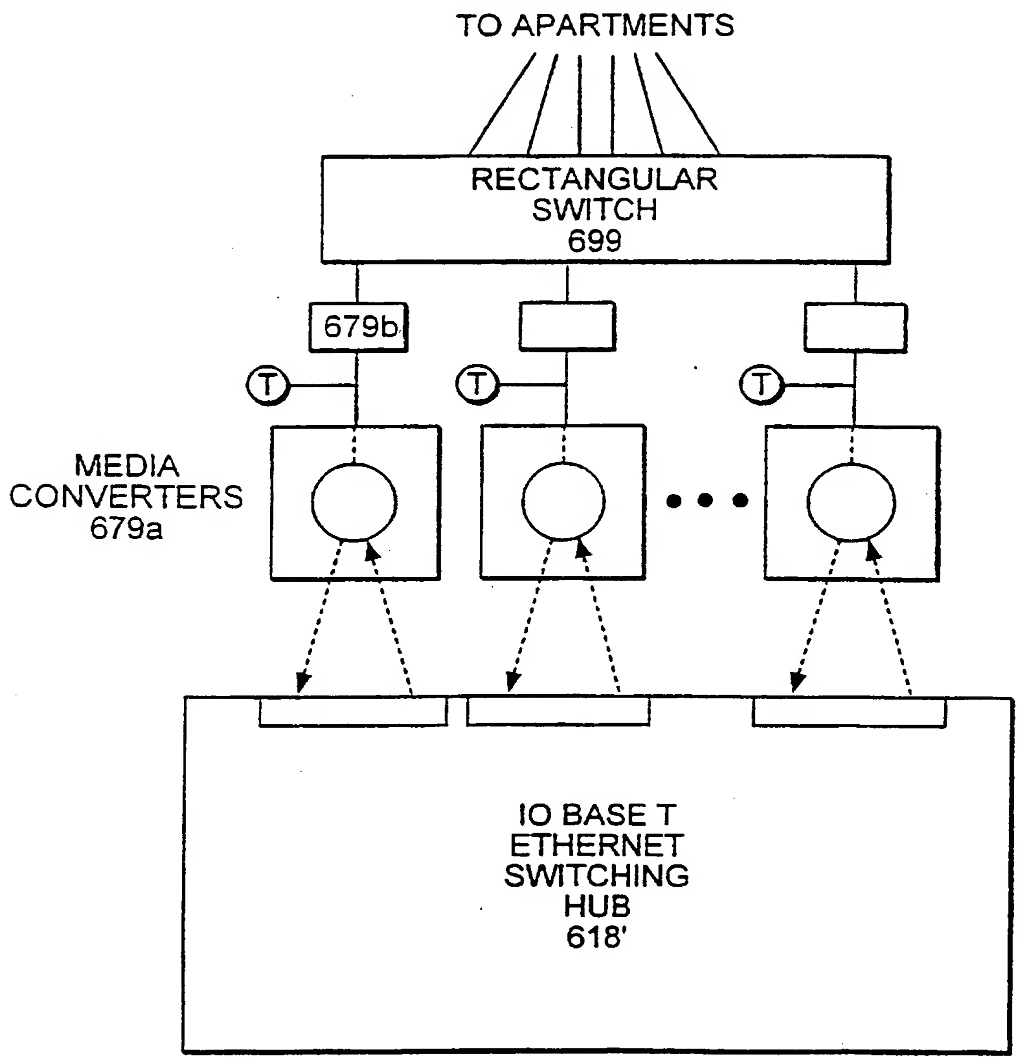

JACK 648
JACK 649
PC 646
MODEM 645a (IO BASE 2 ADAPTER)
661a
LPF 631b
HPF 631a
634
INTERNAL WIRING
LPF 647a
LPF 647
JACK 642a
TO HUB 618 (IO BASE 2 BUS)
TO JACK 642b

FIG. 8b

FIG. 9a


BACKUP TELEPHONE LINK 698b
PBX / VOICE CONCENTRATOR 698a
VOICE/ DC
UPS
HIGH CAPACITY LINE 602
VOICE-ETHERNET LINK 698c
BRIDGE TRANSCEIVER 609a
T
T
ETHERNET LAN (IO BASE 2)
LPF 628
LPF
LPF
LPF
LPF
LPF
TO APARTMENTS
PATCH PANEL 615b
ETHERNET DATA
RECTANGULAR SWITCH 699
HPF 617
HPF
HPF
HPF
AMP/EQUALIZER 699a
IO BASE T ETHERNET SWITCHING HUB 618'



TO APARTMENTS
RECTANGULAR
SWITCH
699
679b
T
T
T
MEDIA
CONVERTERS
679a
IO BASE T
ETHERNET
SWITCHING
HUB
618'

FIG. 9b

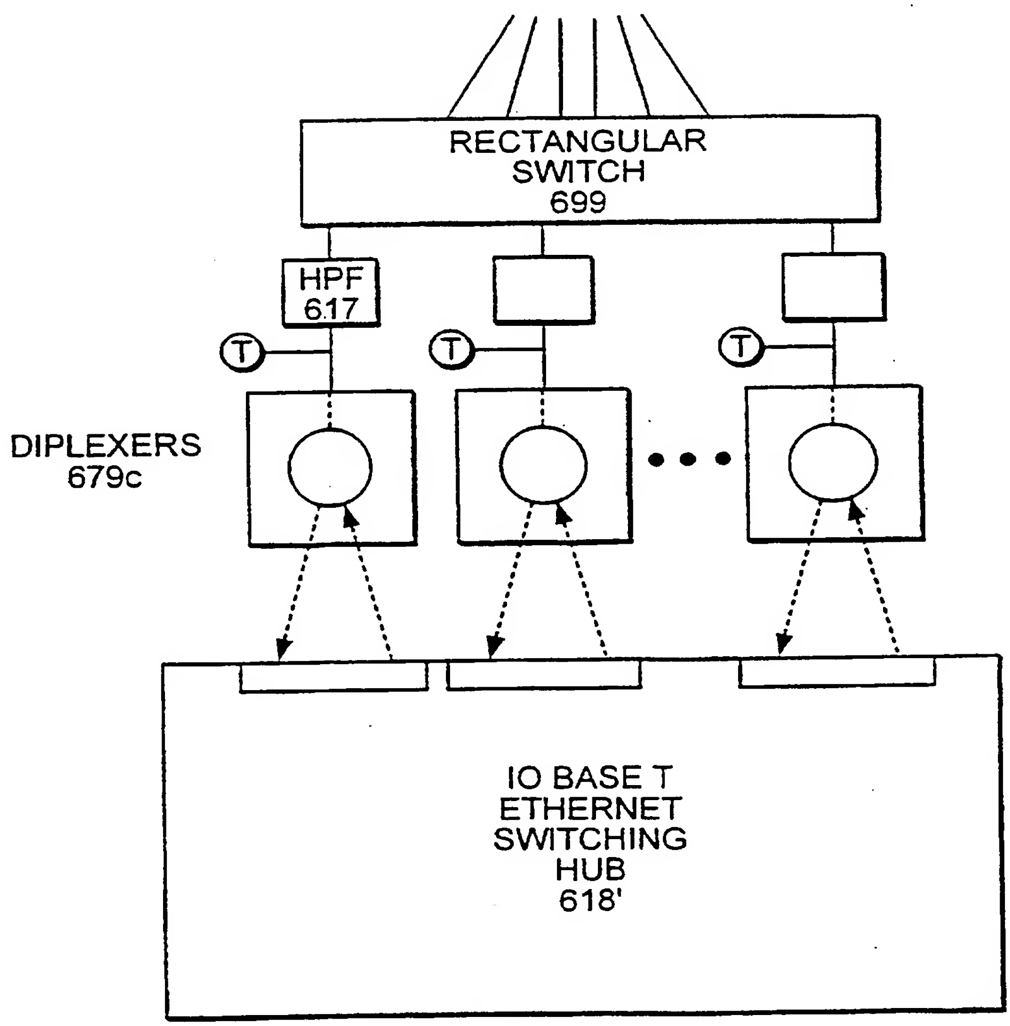

RECTANGULAR
SWITCH
699
HPF
617
T
T
T
DIPLEXERS
679c
IO BASE T
ETHERNET
SWITCHING
HUB
618'

FIG. 9c

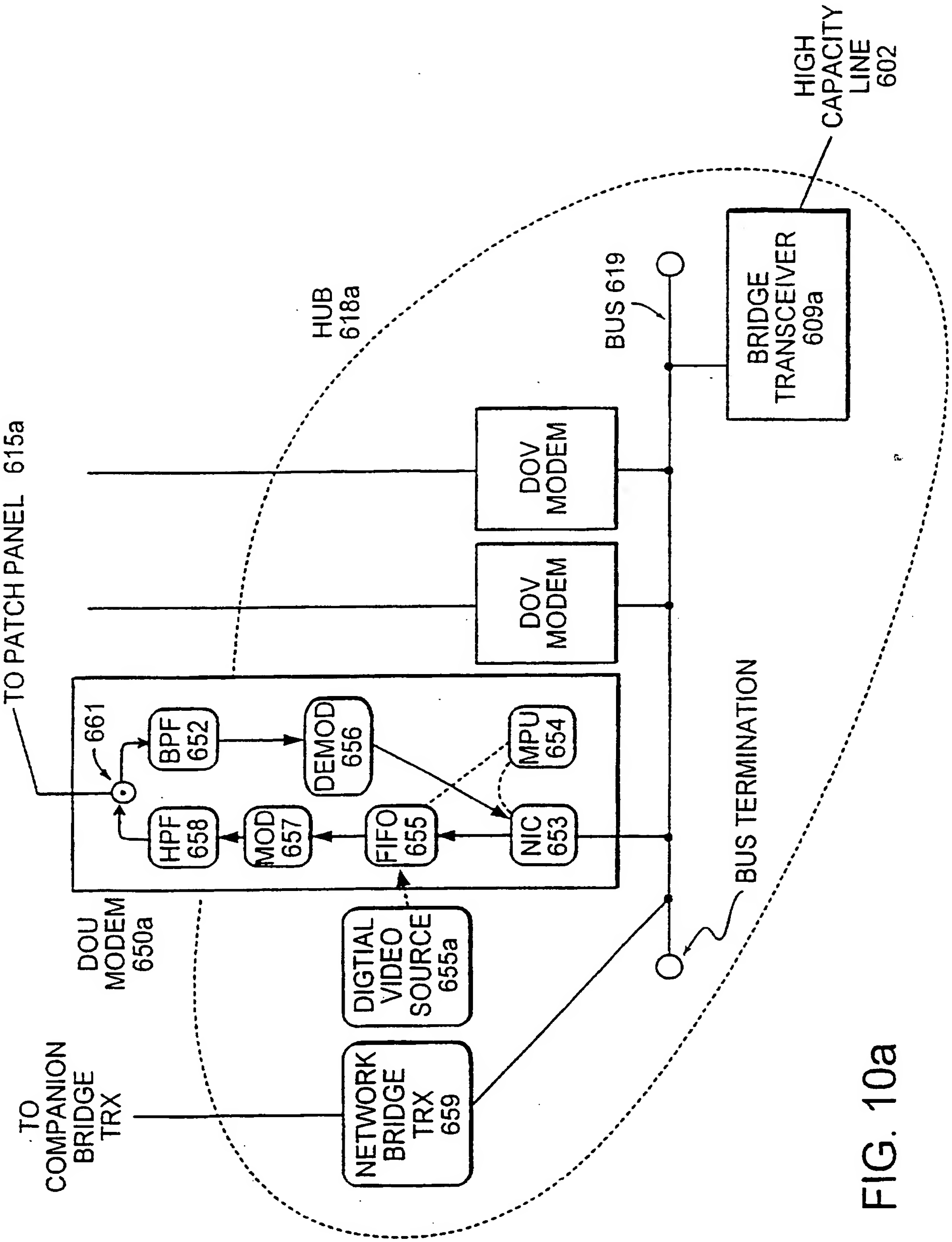

TO PATCH PANEL 615a
HUB 618a
HIGH CAPACITY LINE 602
BUS 619
BRIDGE TRANSCEIVER 609a
DOV MODEM
DOV MODEM
661
BPF 652
DEMOD 656
MPU 654
HPF 658
MOD 657
FIFO 655
NIC 653
BUS TERMINATION
DOU MODEM 650a
DIGTIAL VIDEO SOURCE 655a
TO COMPANION BRIDGE TRX
NETWORK BRIDGE TRX 659

FIG. 10a

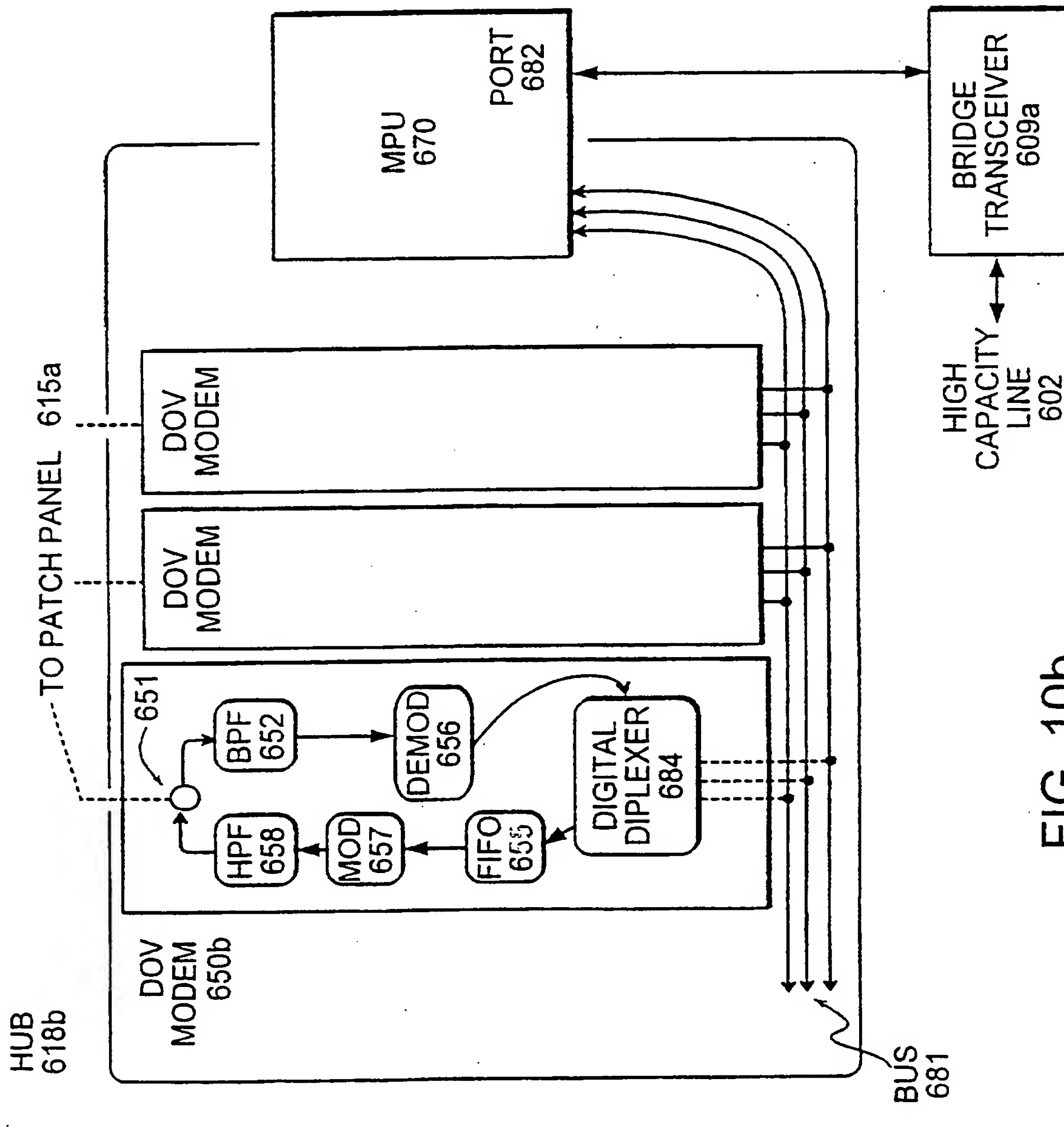

HUB
618b
DOV
MODEM
650b
TO PATCH PANEL 615a
651
BPF
652
DEMOD
656
DIGITAL
DIPLEXER
684
FIFO
655
MOD
657
HPF
658
DOV
MODEM
DOV
MODEM
MPU
670
PORT
682
BRIDGE
TRANSCEIVER
609a
HIGH
CAPACITY
LINE
602
BUS
681

FIG. 10b

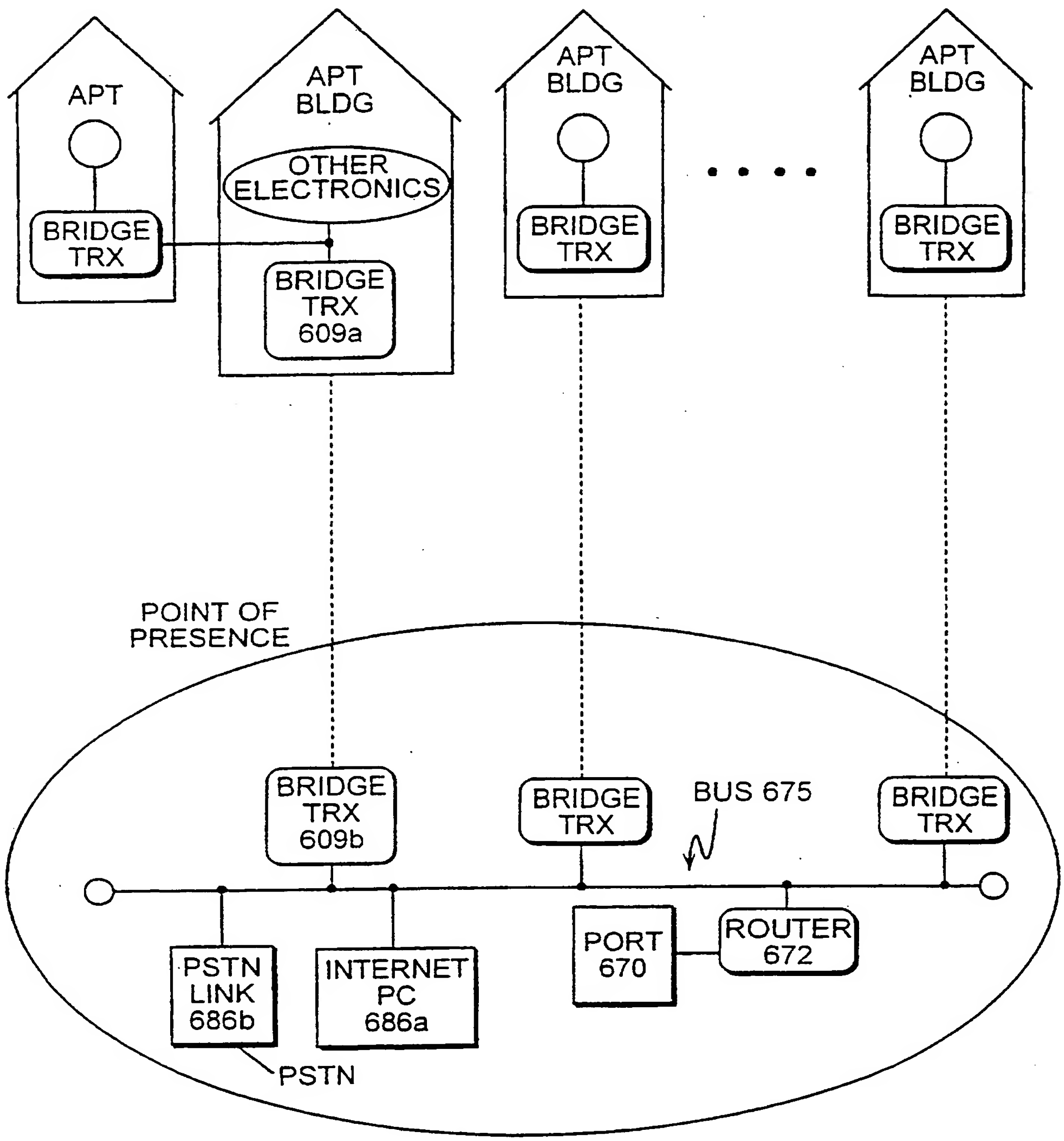


FIG. 11

SUBSTITUTE SHEET (RULE 26)

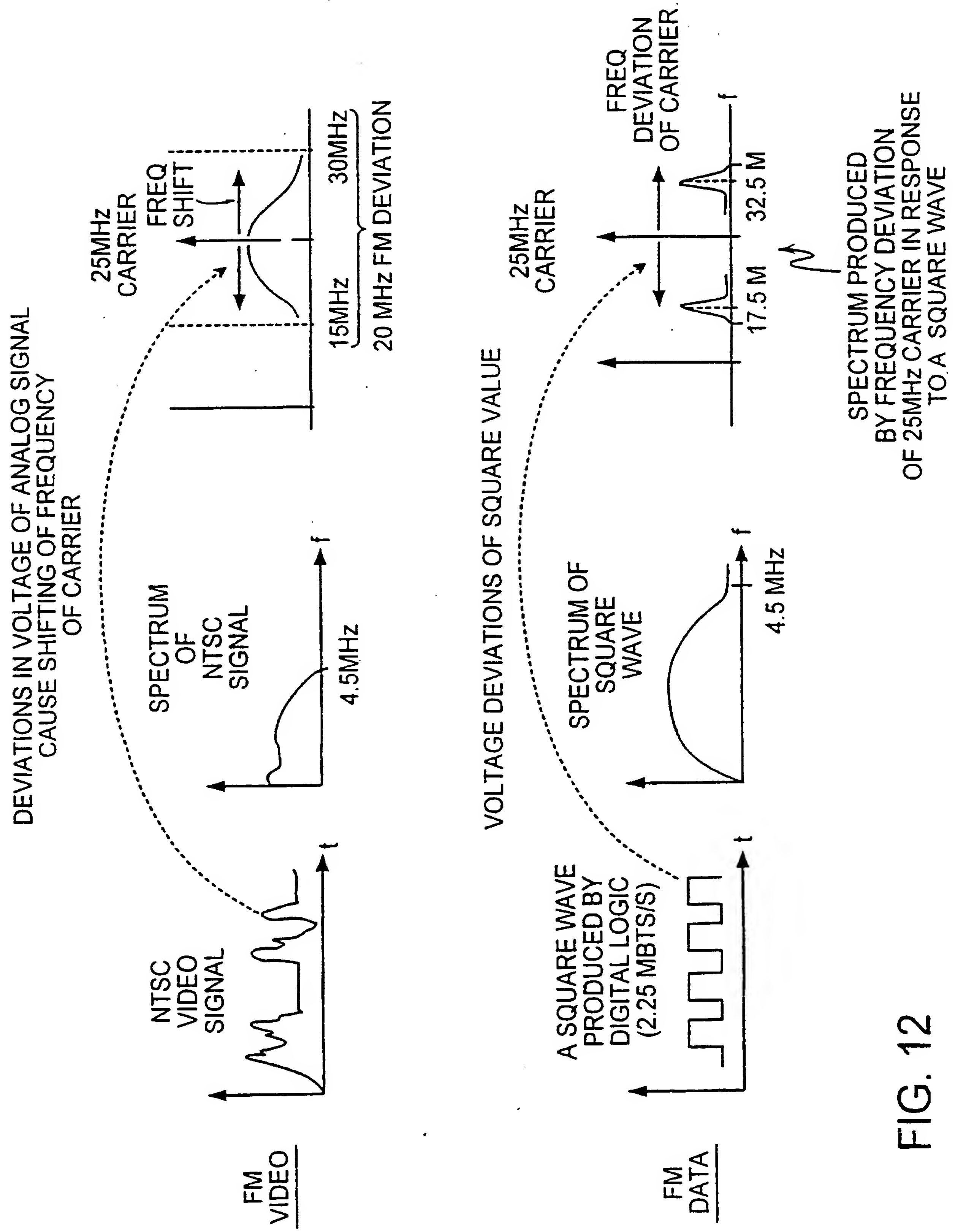

FM VIDEO
NTSC VIDEO SIGNAL
t
DEVIATIONS IN VOLTAGE OF ANALOG SIGNAL CAUSE SHIFTING OF FREQUENCY OF CARRIER
SPECTRUM OF NTSC SIGNAL
4.5MHz
f
25MHz CARRIER
FREQ SHIFT
15MHz
30MHz
20 MHz FM DEVIATION
FM DATA
A SQUARE WAVE PRODUCED BY DIGITAL LOGIC (2.25 MBTS/S)
t
VOLTAGE DEVIATIONS OF SQUARE VALUE
SPECTRUM OF SQUARE WAVE
4.5 MHz
f
25MHz CARRIER
FREQ DEVIATION OF CARRIER
17.5 M
32.5 M
f
SPECTRUM PRODUCED BY FREQUENCY DEVIATION OF 25MHz CARRIER IN RESPONSE TO A SQUARE WAVE

FIG. 12

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/12045

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H04J 1/00, 1/02; H04M 11/00
US CL :370/494, 910; 379/93, 291
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 370/352, 357, 362, 420, 421, 480, 484, 489, 490, 493,494, 522, 527, 529, 910; 379/90, 93, 94, 268, 269, 291, 335

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
APS: VOICE, FREQUENCY BAND, HUB, BUS, ETHERNET

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 3,937,889 A (BELL, III et al) 10 February 1976, abstract, col. 6, line 19 to col. 9, line 8, and Fig. 1.	1-5
Y	US 4,785,448 A (REICHERT et al) 15 November 1988, col. 4, lines 5-62.	1-5
A	US 4,608,686 A (BARSELLOTTI) 26 August 1986, see entire document.	1
A	US 4,953,160 A (GUPTA) 28 August 1990, see entire document.	1
A,P	US 5,546,385 A (CASPI et al) 13 August 1996, see entire document.	1-5
A,P	US 5,579,308 A (HUMPLEMAN) 26 November 1996, see entire document.	1-5

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier document published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	"&" document member of the same patent family

Date of the actual completion of the international search 20 SEPTEMBER 1997	Date of mailing of the international search report 12 NOV 1997
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer ALPUS H. HSU Telephone No. (703) 305-4377

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H04J 1/00, 1/02, H04M 11/00

A1

(11) International Publication Number: WO 98/02985

(43) International Publication Date: 22 January 1998 (22.01.98)

(21) International Application Number: PCT/US97/12045

(22) International Filing Date: 11 July 1997 (11.07.97)

(30) Priority Data:
60/021,651 12 July 1996 (12.07.96) US

(71) Applicant *(for all designated States except US)*: INLINE CONNECTION CORPORATION [US/US]; 730 N. Danville Street, Arlington, VA 22201 (US).

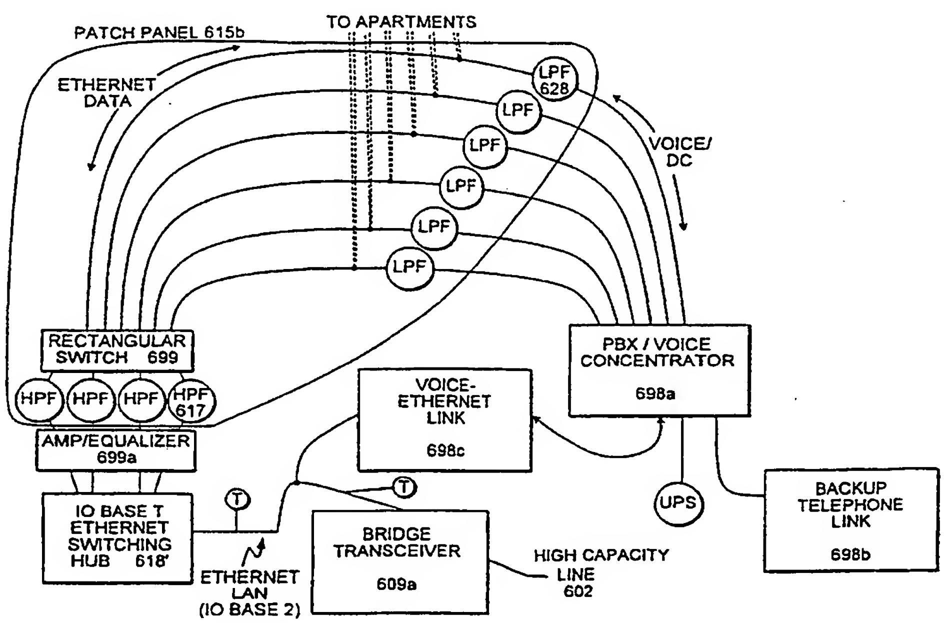
(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: GOODMAN, David, D. [US/US]; 730 N. Danville Street, Arlington, VA 22201 (US).

(74) Agent: WALPERT, Gary, A.; Fish & Richardson P.C., 225 Franklin Street, Boston, MA 02110-2804 (US).

(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, US, UZ, VN, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: DIGITAL COMMUNICATION SYSTEM FOR APARTMENT BUILDINGS AND SIMILAR STRUCTURES USING EXISTING TELEPHONE WIRES



(57) Abstract

A digital communication system for apartment buildings and similar structures using existing telephone wires includes a switching hub (618') for directing information from a source selectively to ones of a plurality of switch lines as signals in a selected frequency band that exceeds frequencies of any voice signals on a telephone link, a switch (699) for coupling each switch line selectively to one of m phone lines, and circuitry for controlling the switch (699).

*(Referred to in PCT Gazette No. 23/1998, Section II)

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CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon			PL	Poland		
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CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		